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Arroyo Center

Analysis of Air-Based Mechanization and Vertical Envelopment Concepts and Technologies

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Prepared for the
United States Army

Approved for public release; distribution unlimited.

The research described in this report was sponsored by the United States Army under Contract No. DASW01-96-C-0004.

ISBN: 0-8330-2966-5

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Published 2001 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 102, Pittsburgh, PA 15213-1516
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PREFACE

This document summarizes research conducted in 1998 by the RAND Arroyo Center on an exploration and assessment of the ability to insert mechanized forces in enemy-controlled terrain. We specifically investigated the use of tilt-rotor aircraft for vertical envelopment concepts, with particular emphasis on survivability implications and the potential enabling role that technology can play. The vertical envelopment concept used for this study was that of rapid deployment of an air-mechanized Army After Next (AAN) battle force into ambush positions against the second echelon of an invading Red force. The work involved the application of high-resolution, force-on-force simulation for the quantitative analysis. Although the research was conducted prior to the Army's current transformation efforts and used a conventional Russian-based threat, it can still provide useful insights into some of the challenges of tomorrow's nonlinear battlespace. The results of the research should be of interest to defense policymakers, concept and materiel developers, and technologists.

We note that the air-mechanized (air-mech) battle force design and employment concept used in this study represented the work of the AAN study project in the FY96–98 timeframe and has no relationship to the current "Air–Mech" concepts proposed by BG (ret.) David Grange and others.* The "battle force" was a notional design construct used by AAN to analyze possible future organizational constructs without the constraints of current unit paradigms. The air-mech concept explored was the organic capability, within a battle force, to air maneuver both troops and medium-weight combat systems at both tactical and operational depths. TRADOC's Army Transformation Study, Wargaming, and Analysis effort has replaced the idea of organic operational airlift of systems with a more general-purpose capability for external lift assets (Army and/or joint) to enable operational maneuver by Objective Force units.

*David Grange et al., *Air-Mech-Strike: 3-Dimensional Phalanx; Full-Spectrum Maneuver Warfare to Doinate the 21st Century,* Paducah, KY: Turner Publications, August 2000.

We also note that the term "vertical envelopment" as used in this report means the use of rotorcraft (including tilt-rotor aircraft) to vertically insert a battle force to conduct an offensive maneuver in which the main attacking force passes around or over the enemy's principal defensive positions to secure objectives to the enemy's rear. Today, vertical envelopment includes other than purely "vertical" means (i.e., SSTOL) and could clearly involve other forms of maneuver (infiltration, turning movement). TRADOC has also recognized the inherent risks in directly attacking enemy air and ground defenses (risks described in this document) and has acknowledged the need for indirect approaches and offset landings, using the ground maneuver capability of the Objective Force to close with the enemy after the air maneuver.

This work was conducted for the U.S. Army Training and Doctrine Command and the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, within the Force Development and Technology Program of RAND Arroyo Center. The Arroyo Center is a federally funded research and development center sponsored by the United States Army.

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SUMMARY

BACKGROUND

During General Dennis Reimer's tenure as the Chief of Staff of the Army (1996–2000), he tasked Training and Doctrine Command (TRADOC) to "conduct broad studies of warfare to about the year 2025, frame issues vital to the development of the U.S. Army after about 2010, and provide issues to senior Army leadership in a format suitable for integration into TRADOC combat development programs." TRADOC led a multi-agency study that investigated and assessed new concepts for a highly "air-mobile" mechanized force in the 2015–2025 time frame.

The Army After Next (AAN) AR 5-5 study was an exploratory process, one that investigated and assessed new ideas for helping shape the far future of the U.S. Army. Arguably, the most visible and identifiable aspect of the AAN process was the annual strategic and operational-level war game, held at the Army War College in Carlisle, Pennsylvania. Prior to this major event, however, there were a number of operational- and tactical-level activities and associated analyses that helped provide greater analytic rigor to the AAN process. This research, conducted in 1998, was one part of this process.

In the past, RAND has used high-resolution constructive simulation as a tool to explore and assess the military utility of new warfighting concepts and underlying, enabling technologies. The simulation tools are useful for two primary reasons. First, and most apparent, the simulation can be used to help quantify outcomes of highly complex force-on-force interactions, which are driven by system-level inputs. Through careful sensitivity and parametric analysis, these outcomes can identify high-payoff, high-leverage areas of technology. Second, simulation can provide context to warfighting concepts. By defining force entities and laying out their associated battle plans on digitized terrain, a simulation can provide many useful insights. Often, this

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process helps to reshape and refine ideas on how such notional forces might fight, and under what situations and conditions they may be effective.

We note that this research was based on best available threat and U.S. data, a limited set of tactics, techniques, and procedures, and our assessment of countermeasures available in the 2020 time period. While we used a conventional Cold War threat and a conventional scenario, and the analysis was specific to the vertical air-ground insertion of AAN combat forces in an enemy-controlled battlespace, we believe the analysis gives important insights into the critical issues for any air-inserted force, such as the Objective Force as proposed in the Army Vision and the Army Transformation Campaign Plan.

SCENARIO

For the research conducted in this study, we focused on a single scenario on mixed terrain exploring the implications of air-based mechanization and vertical envelopment concepts. Generally, scenarios can vary not only in terrain characteristics, but also threat sophistication, environmental conditions, and other factors, resulting in a wide range of results. The scenario we selected for this analysis was developed with input from TRADOC and TRADOC Analysis Center (TRAC). It constitutes a rapid defense/counterattack against a highly advanced attacking armor/mech force, and takes place over a relatively large region.* Air-mechanized (air-mech) battle units were deployed to stop the attack. This was deemed achievable via deep insertion and ambushing of the enemy's elite second echelon. Figure S.1 depicts the scenario used for this analysis. We note that the Red force is a conventional threat, based on Russian army doctrine. At the time of this research, this was the baseline threat used for some of the early AAN war games.

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*The threat consists of a modified version of Red forces as defined by SAIC, NGIC, and TRADOC for AAN analysis and wargaming. The threat in this scenario contains 1,500+ threat vehicles, including 200 attack helicopters. The area modeled is a subsection of the battlespace the Blue force can maneuver in. We specifically chose a battlespace that would challenge AAN concepts and give insights on its capabilities as a function of increasing enemy air defenses.

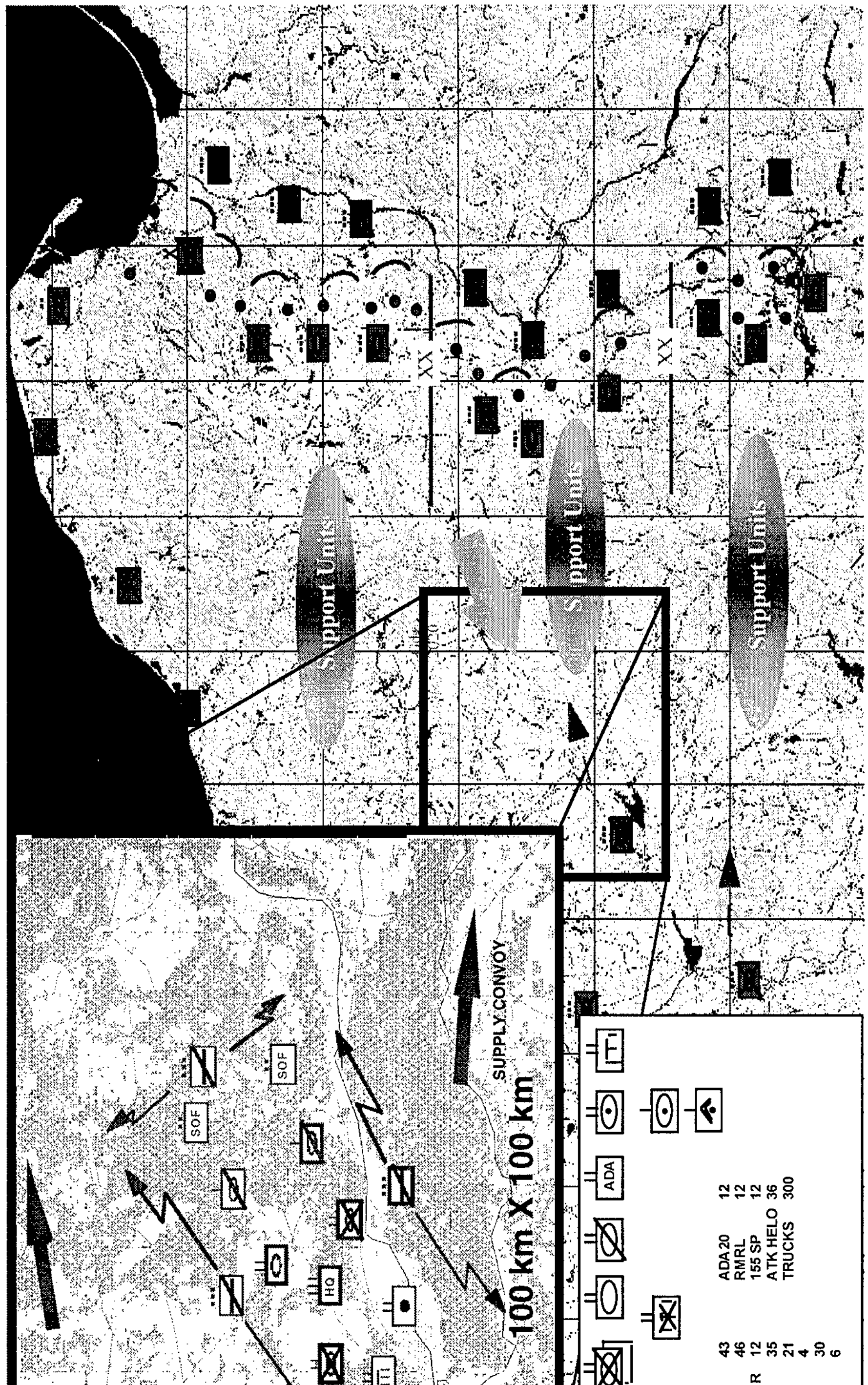

Figure S.1—Scenario Used for Analysis

The air-mechanized battle force concept is divided into two phases: the air maneuver or insertion of the force and the ground combat operation. In this year's effort, we began with a detailed analysis of the air maneuver phase. Using data from a variety of intelligence sources,* we developed a laydown of a hypothetical air defense for a relatively large region which would provide extensive protection against opposing aircraft and against a highly advanced attacking armor/mech force. The air defense network used in our simulation and subsequent analysis is shown in Figure S.2.

The laydown shown in Figure S.2 is intended to represent a "competent" opponent of the 2020 era. Today, the Russian army is capable of fielding the type of air defense system shown here. In coming years, many other forces may have the potential to employ similar integrated air defense systems. We note that beam rider and imaging infrared (IR) missiles, helicopter "mines," and upgrade radio frequency (RF) guided missiles are available now and are not included in this notional enemy integrated air defense network (IAD). Our intent was to start with a readily obtained and manned IAD system in the 2020 time frame, and then investigate a more sophisticated IAD in a future study.

FINDINGS

Air Maneuver Phase

Our initial findings are based on a specific stressing scenario with a conventional Russian air defense artillery (ADA) threat and a limited set of Blue force tactics and technology. We present these findings as a starting point for future research, not as a definitive analysis on the feasibility or military utility of the AAN air-mech concept.

We examined the ability of the notional AAN advanced airframes (AAF) to survive the initial air maneuver/insertion required in our scenario under a variety of conditions. These included: level of SA (situational awareness) and intelligence provided to pilots, level of

*Discussions in 1997 and 1998 with DIA and NGIC representatives, and analysis of associated documentation.

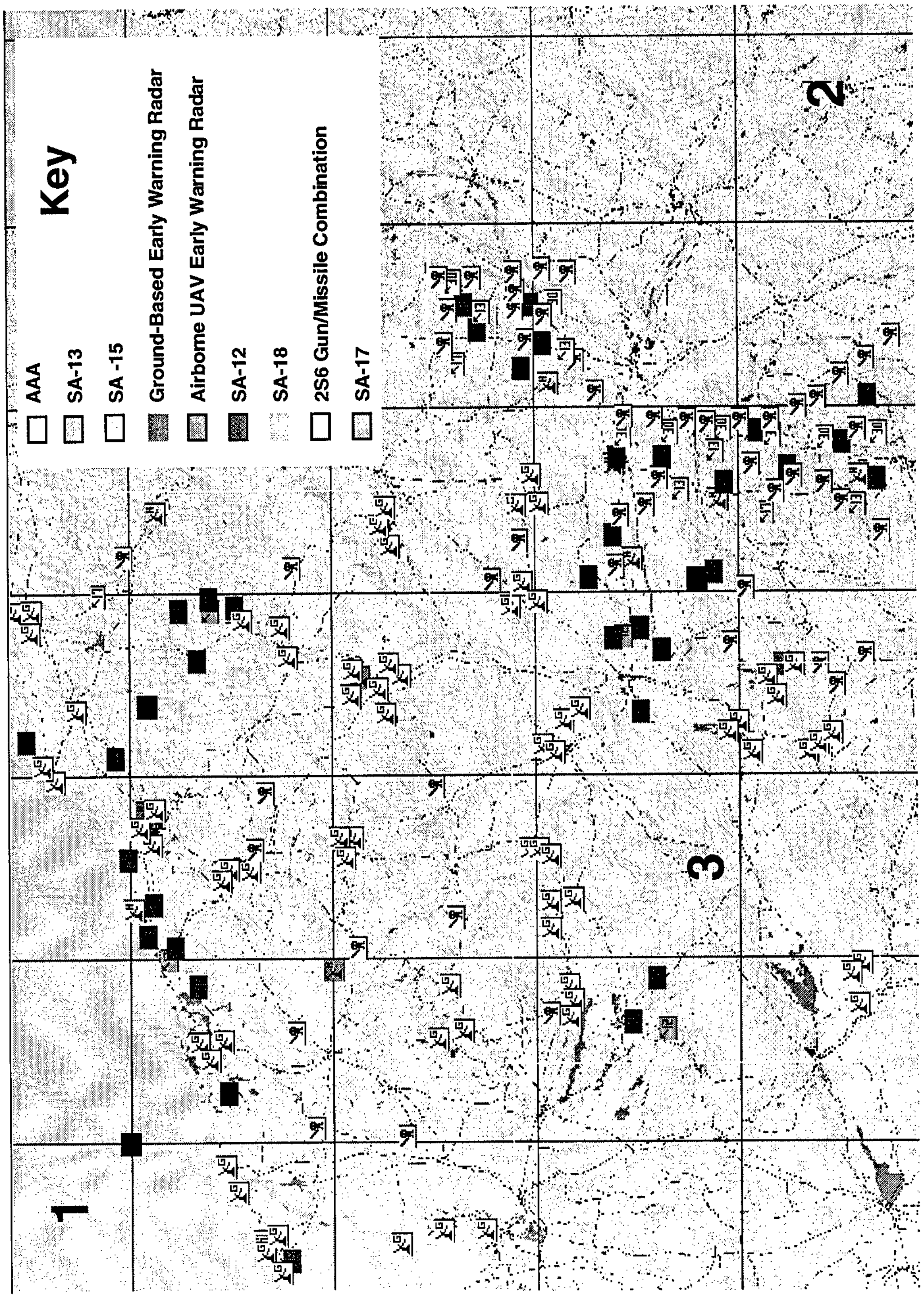

Figure S.2—Enemy Air Defense Network Used for Initial Phase of Analysis

SEAD (suppression of enemy air defenses), flight tactics and ingress routes used by the pilots, and signature characteristics of the airframes (both RF, IR, and optical).

The results of our analysis are summarized in Table S.1. Blank spaces in the table mean that the specific case was not examined. We were able, by careful selection of the cases we modeled, to parametrically explore a fairly wide range of possible missions the AAN force might face. In general, high levels of SEAD, increased situational awareness (intelligence on the locations of high-end enemy air defense systems), special flight tactics, and stealth were major factors affecting survivability. In regions that have significant amounts of optical and IR-guided anti-aircraft weapons, loss rates are deemed to be fairly high (above 10 percent). We did not model the effects of small arms fire, which could increase the losses. Initial findings from RAND Arroyo Center research started in late 2000 indicate losses from 12.7mm (50 caliber) machine guns can, under specific conditions, be fairly high. Flying above short-range weapons did improve survival rates, but only when high-altitude, long-range enemy air defenses could be fully suppressed (something that may be difficult to attain early in a conflict). Reduction in signature helped reduce the envelope in which engagements took place; but because of the relatively slow speeds of the aircraft (100 to 250 knots), the infrared surface-to-air missiles (IR SAMs), in most cases, still had sufficient time to engage the AAFs.

Discussions with individuals familiar with Air Force operations indicated that a similar challenge exists for the fixed-wing platforms that are envisioned to conduct deep strike or interdiction missions.* Our analysis at this point reflects that air maneuvering of ground forces behind enemy lines (with relatively large aircraft) is likely to remain a challenge—even with the aggressive incorporation of any single technology area. Rather, we found that a combination of technologies and tactics, techniques, and procedures (TTPs) would probably be necessary.

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*Informal discussions with Air Force officers at DIA and analysts from Project AIR FORCE at RAND.

Table S.1

Summary of Air Maneuver Survivability Results: Percent of AAN AAF Surviving the Mission

Flight path description/ creator	Parameters examined											
	Medium-level SA						High-level SA					
	No SEAD		Medium SEAD		High-level SEAD		No SEAD		Medium SEAD		High-level SEAD	
	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig
Baseline/ RAND analyst	0%	0%			0%	25%						
Low & slow/ RAND analyst*	40%	57%			93%	98%	62%	79%	79%	88%	93%	100%
Low & fast/ Navy pilot							19%	63%	56%	87%	56%	87%
Very low & slow/ Army pilot											62%	87%
Medium altitude/ Navy pilot							0%		100%			

DEFINITIONS: Medium-level SA provides Intel on 50% of SAMs (type and location); high-level provides 100% Intel. No SEAD means all AD units active; medium SEAD means SA-12s, SA-17s removed; high-level SEAD means SA-12s, SA-17s, SA-15s, and 2S6s removed.
Base signature corresponds to AAF; LO signature corresponds to notional level of stealth.

*Over-water-only cases.

In addition to the technology and TTPs examined, other options may have important effects on mission success. Technologies that should be investigated include advanced infrared and RF countermeasures, optical dazzlers, and stealth technologies. Tactics such as unmanned insertion of the combat vehicles, the use of decoys, and preemptive Special Operations Forces (SOF) insertion of the combat crews to neutralize air-defended areas may also provide other solutions.

The results of this part of the study should not be interpreted as the final word on air-mech operations in enemy airspace, but as a first look at a complex problem. We believe this research shows the magnitude of the problem and provides important insights on potential solution sets. Many of these insights are relevant for the Army's current transformation efforts and should be used as a starting point for

research in the deployability and survivability of these new "medium weight" forces.

Ground Combat Phase

The air-mech battle force will have to balance fast deployability with the requirements for survivability and lethality. Our initial research indicates that USTRANSCOM (United States transportation command) will be able, under optimistic assumptions, to provide the Army with a strategic airlift capability of roughly 3,000 tons per day. This will severely limit the amount and types of combat vehicles that can be deployed. This, we believe, is the critical design challenge for air-mech ground forces.

By conventional thinking, the survivability of ground vehicles is generally improved by increasing their weight. In missions where a ground combat vehicle will only be exposed to small arms fire, a 10-ton-class vehicle may have sufficient all-around protection. However, if the vehicle is likely to face larger-caliber weapons (e.g., 30mm rounds), then significant armor projection will be required; based on historical data, its weight would put it roughly into a 30-ton class.

The use of new technologies can begin to reshape how we think about weight and protection. For example, the use of active protection systems (APS) can offer some defense against chemical explosive (CE) weapons with very little additional weight (see Figure S.3). SARDA has calculated that the use of APS and reactive armor can result in 30-ton vehicles that offer the survivability of today's M1A2 tank. TRADOC envisions even lighter-weight combat vehicles. Current Future Combat Systems research is attempting to reduce this weight to less than 20 tons.

The need for heavy armor will be a function of the proposed air-mech mission. Forces consisting of primarily lighter vehicles can be considered if direct-fire fights are avoided and indirect-fire missiles can be countered. The use of advanced sensors and robotics can help significantly in these two areas.

For other missions, such as military operations on urban terrain (MOUT), heavier vehicles may be required. We plan to use high-resolution modeling to explore the capabilities of TRADOC-developed

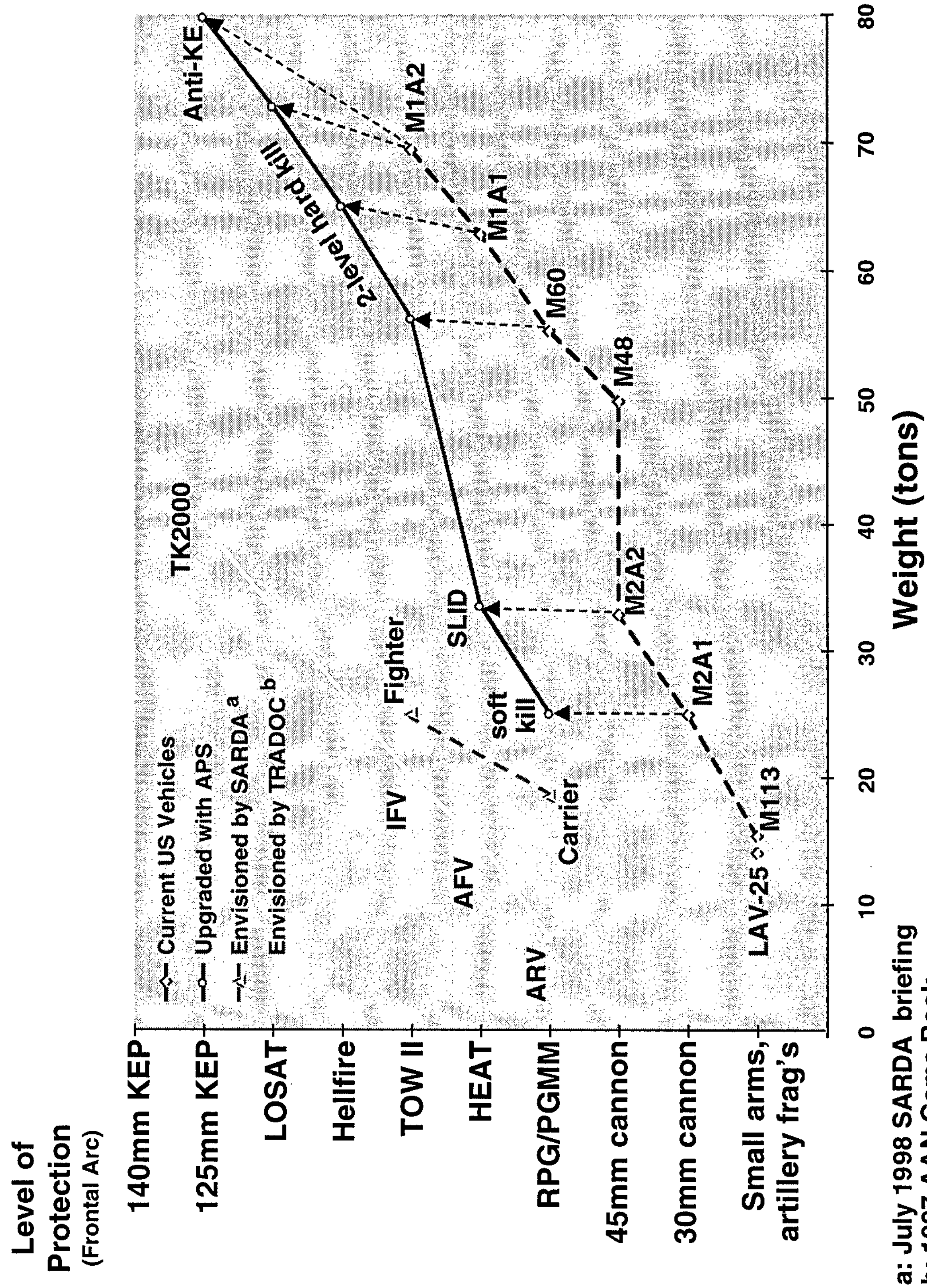

Figure S.3—Increased Protection Often Leads to Significantly Greater Vehicle Weight

air-mech forces, in offensive and defensive operations. Key to this exploratory study will be the development of measures of effectiveness (MOEs). Given the nonlinear deployment of the air-mech forces, new MOEs will be needed. Initial research indicates that shock and disruption will be MOEs as useful as attrition.

We note that the Army's Objective Force goals are remarkably consistent with the TRADOC AAN air-mech forces' goals.

INSIGHTS

This research suggests that a combination of technologies and tactics are needed to perform the air-insertion portion of an air-mech mission. The quantity and quality of the enemy's air defenses will determine what combinations are needed, and what level of success will occur. Long-range RF SAMs were found to be the principal threat to aircraft. Several sets of tactics and technologies can minimize the exposure of the aircraft to these SAMs. Given appropriate tactics and technologies for dealing with the RF SAM threat, we found that the limiting factor will then be the amount of optically and IR-guided air defense systems the air-mech forces are exposed to. Cross-FLOT* missions, in particular, were found to expose the aircraft to significant amounts of anti-aircraft artillery (AAA) and IR SAMs and resulted in high losses. Critical for the success of this phase of the mission will, therefore, be the development of technologies and tactics to deal with this optical/IR threat. We propose two approaches that have the potential to minimize the AAA and IR SAM threats.

The air-mech battle force needs to be significantly lighter than current forces. This is also true of the current Objective Force as envisioned by General Shinseki. Because the survivability of combat vehicles has been traditionally related to the amount of armor on the vehicle (i.e., the heavier the vehicle, the more survivable), analysts will thus have to look at a large set of lightweight survivability technologies. In addition, tactics, techniques, and procedures that can minimize the force's exposure to enemy direct fire need to be developed. We expect that a combination of technologies and tactics will be required for the

*FLOT is forward line of troops.

air-mech battle force or Objective Force to be successful on the future battlefield.

INSIGHTS FOR THE OBJECTIVE FORCE

The air-insertion analysis performed in this study provided baseline assessments on the quantities and types of air defenses an adversary would need to limit the Army's ability to conduct this mission. Although we used a conventional threat based on current "Russian" doctrine and technology, we have several initial findings and recommendations for future research efforts that we believe are relevant for Objective Force air-insertion operations in enemy-controlled battlespace.

One key finding was the limiting effect of optically guided anti-aircraft munitions. Further research is needed to better quantify the magnitude of this problem. And, given its severity, additional research is warranted on technologies to counter this problem. One approach in particular (stealth fixed/tilt-wing aircraft) was shown, for our specific scenario, to provide a viable solution to this problem if a secure landing site can be quickly established. This would require a new aircraft program start, an expensive solution in today's limited defense budgets. Another possible solution is active protection systems that can counter both optically guided missiles and AAA. Both approaches should be investigated in future research efforts.

Another critical issue was the high level of RF SAM suppression needed for mission survivability. This may not be feasible with SEAD alone, particularly if the aircraft land in enemy-controlled areas. Research on active RF countermeasures and new tactics will be a critical part of future efforts.

In this initial study we looked at only two sets of air-insertion tactics. Other tactics may have the potential to significantly raise the probability of successful air insertion of the objective force, and should be the subject of future efforts.

Lastly, we looked only at air defense and countermeasure systems that are currently deployed in significant numbers. Laser-guided missiles, imaging IR missiles, and anti-helicopter mines are three examples of

serious AAN air vehicle threats we did not model, but these will probably be available in the 2020 time frame. The modeling and assessment of advanced threats and countermeasures such as laser-based infrared countermeasures (IRCM) will be a critical part of future analytic efforts.

We presented initial research on the ground phase of the air-mech concept, now superseded by the medium-weight force transformation effort. The goals of this force are remarkably similar to those of the AAN air-mech concept: developing the most deployable (i.e., lightest possible, most sustainable) force capable of performing decisive defensive and offensive missions. Future research should, therefore, concentrate on assessing the new medium-weight force being developed by the Army, DARPA, and industry. Leveraging off of previous RAND, Army, and industry research and collaboration with Army agencies, future research efforts will be able to model fighting vehicles of different weight classes. Using the emerging concepts, new TTPs, doctrine, and vehicle capabilities developed by the Army will be the critical first step in the analysis needed for the design/selection of the new medium-weight combat force.

ABBREVIATIONS

AAA	Anti-Aircraft Artillery
AAF	Advanced Airframe
AAN	Army After Next
ADA	Air Defense Artillery
AEF	Air Expeditionary Force
AFV	Advanced Fighting Vehicle
AGL	Above Ground Level
APS	Active Protection System
ARL	Army Research Laboratory
ARO	Army Research Office
ARV	Advanced Reconnaissance Vehicle
ASP	Acoustic Sensor Program
ATACMS	Army Tactical Missile System
ATGM	Anti-Tank Guided Munitions
AWACS	Airborne Early Warning and Control System
BAT	Brilliant Anti-Armor submunition
C2	Command and Control
C3	Command, Control, and Communications
CAGIS	Cartographic Analysis and Geographic Information System
CE	Chemical Explosive
CHAMP	CAGIS Helicopter Advanced Mission Planner
CONUS	Continental United States

DARPA	Defense Advanced Research Projects Agency
DBSM	Decibels per Square Meter
DCSDOC	Deputy Chief of Staff for Doctrine
DFAD	Digital Feature Attribute Data
DSB	Defense Science Board
EFOG-M	Enhanced Fiber Optic Guided Missile
FDC	Fire Direction Center
FLOT	Forward Line of Troops
IAD	Integrated Air Defense
IFV	Infantry Fighting Vehicle
IR	Infrared
KEP	Kinetic Energy Projectile
KM	Kilometer
KTO	Kuwaiti Theater of Operations
KTS	Knots
LO	Low Observable
LOS	Line of Sight
MADAM	Model to Assess Damage to Armor with Munitions
MANPADS	Man-Portable Air Defense System
MOE	Measure of Effectiveness
MRMC	Medical Research Materiel Command
MSR	Main Supply Route
NDRI	National Defense Research Institute
ODS	Operation Desert Storm

RCS	Radar Cross-Section
RF	Radio Frequency
RISTA	Reconnaissance, Intelligence, Surveillance, and Target Acquisition
RJARS	RAND's Jamming Aircraft and Radar Simulation
RPG	Rocket Propelled Grenade
RTAM	RAND's Target Acquisition Model
SA	Situational Awareness
SAM	Surface to Air Missile
SARDA	Secretary of the Army for Research, Development, and Acquisition
SEAD	Suppression of Enemy Air Defenses
SEMINT	Seamless Model Integration
SIRCM	Suite of Integrated Infrared Countermeasures
SIRFC	Suite of Integrated Radio Frequency Countermeasures
SLID	Supersonic Low Cost Interceptor
TARDEC	Tank and Automotive Research Development and Engineering Center
TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine Command
UAV	Unmanned Aerial Vehicle

Exploring Air-Mech and Vertical Envelopment Concepts and Technologies

This annotated briefing summarizes RAND research conducted in support of the Army After Next (AAN) initiative. RAND supports the AAN effort in a number of different ways; this document only addresses RAND's research in the area of high-resolution simulation. The focus was on the AAN's air-mechanized battle force concept.* This report covers research done in 1998.

We note that the air-mechanized (air-mech) battle force design and employment concept represented the work of the AAN study project in the FY96–98 time frame and has no relationship to the current "air-mech" concepts proposed by BG (ret.) David Grange and others.†

The "battle force" was a notional design construct used by AAN to analyze possible future organizational constructs without the constraints of current unit paradigms. One of the concepts (air-mech) explored was the organic capability, within a battle force, to air

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*1997's effort involved a detailed analysis of the AAN light battle force concept. See John Matsumura et al., *The Army After Next: Exploring New Concepts and Technologies for the Light Battle Force,* Santa Monica, CA: RAND, DB-258-A, 1999.

†David Grange et al., *Air-Mech-Strike: 3-Dimensional Phalanx; Full-Spectrum Maneuver Warfare to Dominate the 21st Century,* Paducah, KY: Turner Publications, August 2000.

maneuver both troops and medium-weight combat systems at both tactical and operational depths. U.S. Army Training and Doctrine Command's (TRADOC's) Army Transformation Study, Wargaming, and Analysis effort has replaced the idea of organic operational airlift of systems with a more general-purpose capability for external lift assets (Army and/or joint) to enable operational maneuver by Objective Force units.

Project Objective

- **Explore and assess new operational concepts and technology options for the vertical envelopment concept**
  - **Team with user and developer communities**
  - **Integrate explorations of operational concepts**
  - **Incorporate assessments of technology**

The objective of this project is to help the U.S. Army explore and assess new operational concepts and technology options within the vertical envelopment context (looking roughly 30 years out). In doing so, our intention was to coordinate our research closely with both user and developer communities. As a result, we could then integrate explorations and assessments of future technologies within a valid framework of operational concepts and vice versa.

Research Issues to Be Addressed
(for Air-Mechanized Battle Force)

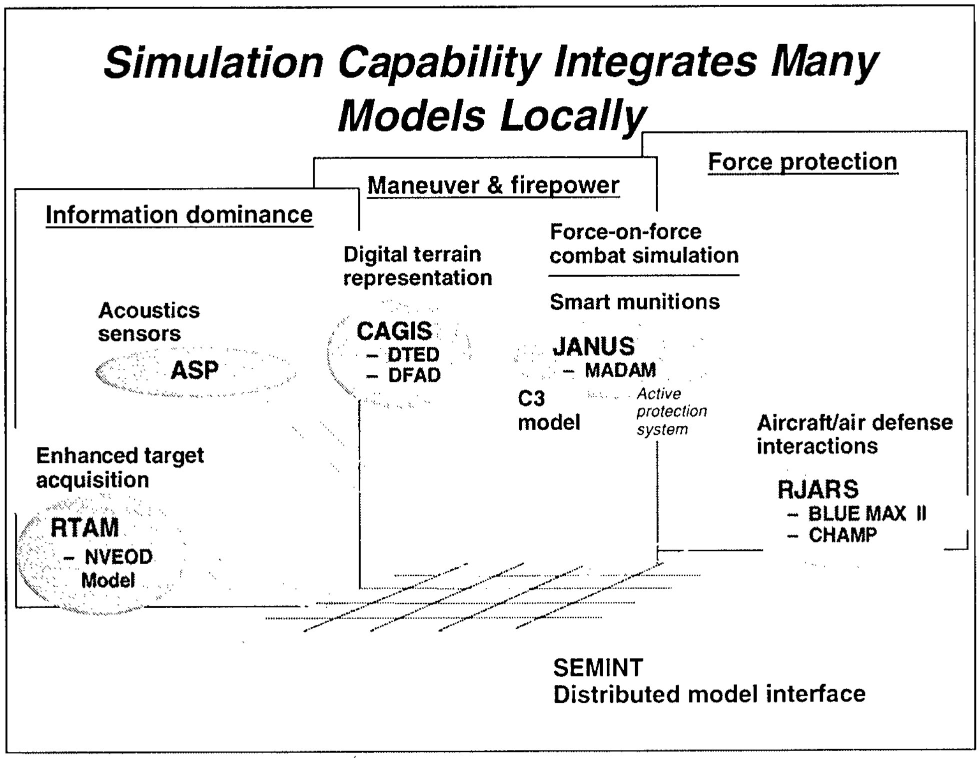
1. **To what extent can survivability be achieved through new tactics, techniques, and procedures (TTPs) and new technology in the areas of:**
   mobility & agility, terrain masking, signature management & control, active protection, lightweight armor, comprehensive situational understanding, deception, and indirect fires?
2. **What are critical components and performance attributes of the air-mech concept and mobility?**
3. **What are appropriate combinations of sensors and weapons for adequate lethality?**

The research issues that we were asked to address by the project sponsors are listed above. Issue number 1 was the key item of focus.

Outline

- **Methodology**
- **Scenario**
- **Air maneuver phase**
- **Ground combat phase**
- **Insights**

This document is organized into five sections. The first section describes our methodology and simulation models. The second section describes the scenario we used to examine vertical envelopment force excursions. The next two sections present our initial findings. The last section discusses our insights from this research and what our next steps will be.

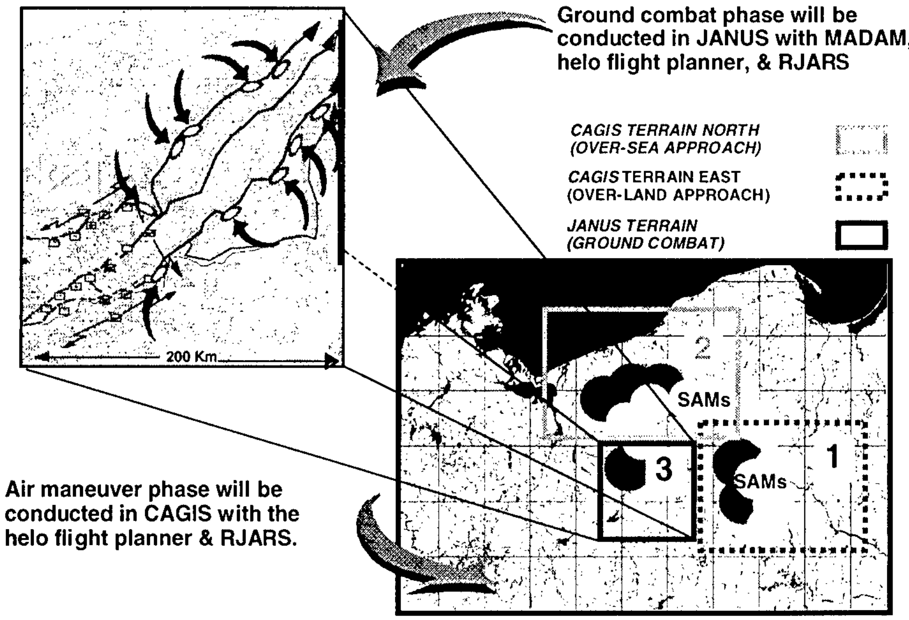


A portion of our research was devoted to modification and development of high-resolution models capable of representing the performance of advanced-technology vertical envelopment systems. The primary vertical envelopment system used for this study was a large derivative of the V-22, capable of vertical take-off and landing with an AAN combat vehicle as its payload. We started with our existing distributed simulation environment for modeling ground combat, developed over the course of several years on other projects. The structure of this distributed environment is diagrammed above.

The RAND version of JANUS serves as the primary force-on-force combat effectiveness simulation and provides the overall battlefield context, modeling as many as 1,500 individual systems on a side. The combination of the RAND Target Acquisition Model (RTAM) and the Cartographic Analysis and Geographic Information System (CAGIS) allows us to represent, as needed, detailed detection/acquisition phenomenology, including those associated with low-observable vehicles. RAND's Jamming Aircraft and Radar Simulation (RJARS) provides a means to simulate the detection, tracking, flyout, and fusing of air defense missiles. The Model to Assess Damage to Armor with Munitions (MADAM) enables us to simulate the effects of smart

munitions, including such aspects as chaining logic, multiple hits, and unreliable submunitions, among others. The Acoustic Sensor Program (ASP) provides a detailed simulation of acoustic phenomenology for such systems as air-delivered acoustic sensors and wide-area munitions. The Seamless Model Integration (SEMINT) allows all of these locally distributed simulations to communicate while running on separate processors.

Research Involves Analysis of Air and Ground Ops



The air-mech concept consists of two distinct phases: the first is the insertion of the battle force, the second is the actual ground combat. Both phases must be successfully completed for mission success. The air-insertion phase represents a significant challenge to the Army.

(For a larger illustration of this scenario, see page 15.)

The use of advanced intelligence assets, aggressive suppression, and destruction of enemy air defense artillery (ADA) will minimize but not eliminate the ADA threat. Athough the Marine V-22 standard operating procedure is to "fly where the enemy ain't," the Army does not always have this option. The ability to transport significant amounts of combat power through areas with some enemy air defense assets is, therefore, a high-payoff capability that could significantly increase the Army's ability to quickly deploy and conduct missions in adverse environments. It was for this reason that we concentrated our first analytic efforts on the air-insertion phase, and specifically the ability of the notional AAN Rotorcraft to deal with various levels of ADA.

Analysis of Air-Mech Battle Force Was Explored in Two Separate Phases

Air maneuver phase

- **Key areas examined: mobility and agility, terrain masking, signature management and control, and comprehensive SA**
- **Primary simulation tools used: CAGIS, CHAMP, and RJARS**

Ground combat phase

- **Key areas examined: all areas listed before, plus coordination of fires**
- **Primary simulation tools used: JANUS, MADAM, CHAMP, and RJARS**
- **New simulation tools: active protection system model**
- **Ongoing effort**

Each phase of the air-mech concept has key areas for which high-resolution modeling can provide critical insight. In the air phase we used CAGIS to model terrain, CHAMP as the aircraft flight planner, and RJARS as the air-ground combat model. CHAMP incorporated SIRFC (suite of Integrated Radio frequency countermeasures), and RJARS incorporated some of the IR countermeasures that will be part of SIRCM (suite of Integrated Infrared countermeasures). We were not able to obtain a complete set of SIRCM specifications during this study, and it should be noted that we did not model all the IR missile countermeasures that may exist in the 2025 period. We did, however, in subsequent studies perform some parametric analysis to bound the problem, and we obtained results similar to what is presented later in this document.

The ground combat phase will utilize additional simulation tools to model the ground-to-ground combat. These include ASP for acoustic sensor representation, a command and control model embedded in JANUS, the MADAM simulation of smart munitions effects, and a separate model for active protection systems.

Matching the Issues to the Methodology

Analysis issues	Air maneuver phase	Ground combat phase
Survivability		
Mobility and agility	x	x
Terrain masking	x	x
Signature management and control	x	x
Active protection system	x	x
Lightweight armor		x
Situational understanding	x	x
Deception/SEAD	x	x
Indirect fires		x
Mobility		
Ingress/egress techniques	x	
Degree of SA	x	x
Tactical positioning	x	x
Sensor/weapon mix		
Ground/air sensors	x	x
Direct/indirect fire	x	x

The high-level vertical envelopment issues are analyzed by breaking them into components that can be modeled. This chart shows what issues we will analyze in each phase of the air-mech battle force deployment.

Incorporating Key Parameters in Simulation

Analysis issues	Representative variations in simulation
Survivability	
Mobility and agility	Adjust vehicle performance measures
Terrain masking	Vary vehicle movement paths
Signature management and control*	Adjust MRC/MRT, VIS/IR/RCS/dB, or P_{acq}
Active protection system*	Add new model to account for technology
Lightweight armor	Increase/decrease P_k by aspect
Situational understanding*	Vary information displayed/used
Deception/SEAD	Add decoys/remove AD systems
Indirect fires	Incorporate different levels of fire support
Mobility	
Ingress/egress techniques	Vary maneuverability and speed
Degree of SA	Modify knowledge of threat
Tactical positioning	Parametrically adjust time to emplace
Sensor/weapon mix	
Ground/air sensors	Adjust numbers, coverage, capability
Direct/indirect fire	Examine various combinations

* Partly addressed by SIRCM and SIRFC and modeled in simulation

Key to our analysis of vertical envelopment issues is the use of the simulation tools. This chart shows how we plan to vary the model parameters to explore the issues.

Outline

- Methodology
- Scenario
- Air maneuver phase
- Ground combat phase
- Insights

In this section we first discuss how and why we selected the scenario for this analysis. We then present the general scenario, describing the air insertion and ground force objectives and threat situation. Details of the air defense are presented in the air maneuver section, and ground forces are further described in the ground combat section.

Motivations for Scenario Adopted

- **Interest in examining deep attack operations with:**
  - **Sufficient battlespace to examine insertion operation, long-range fires, and maneuver**
  - **Mixed terrain**
  - **Early "offensive" ground-force operations**

Getting away from "Desert Storm revisited"

- **Examining issues for which detailed simulation is particularly important**
  - **Survivability of deep insertion**
  - **Feasibility and effectiveness of alternative system configurations and weapons**
  - **Synergism of long-range fires and maneuver with small precision-fire forces**
- **Practicalities: available databases, leveraging ongoing research**

We use several vignettes derived from a single scenario. The particular one used was selected because it was stressing. It exercised all the aspects of the vertical envelopment air-mech concept.

The scale and topography lent itself well to deep attack operations. The battlespace is, by some interpretations, relatively shallow (several hundred kilometers), yet large enough to encourage joint operations and elements of maneuver. The terrain is also sheltered enough to provide cover for an advance, unlike the terrain in Desert Storm.

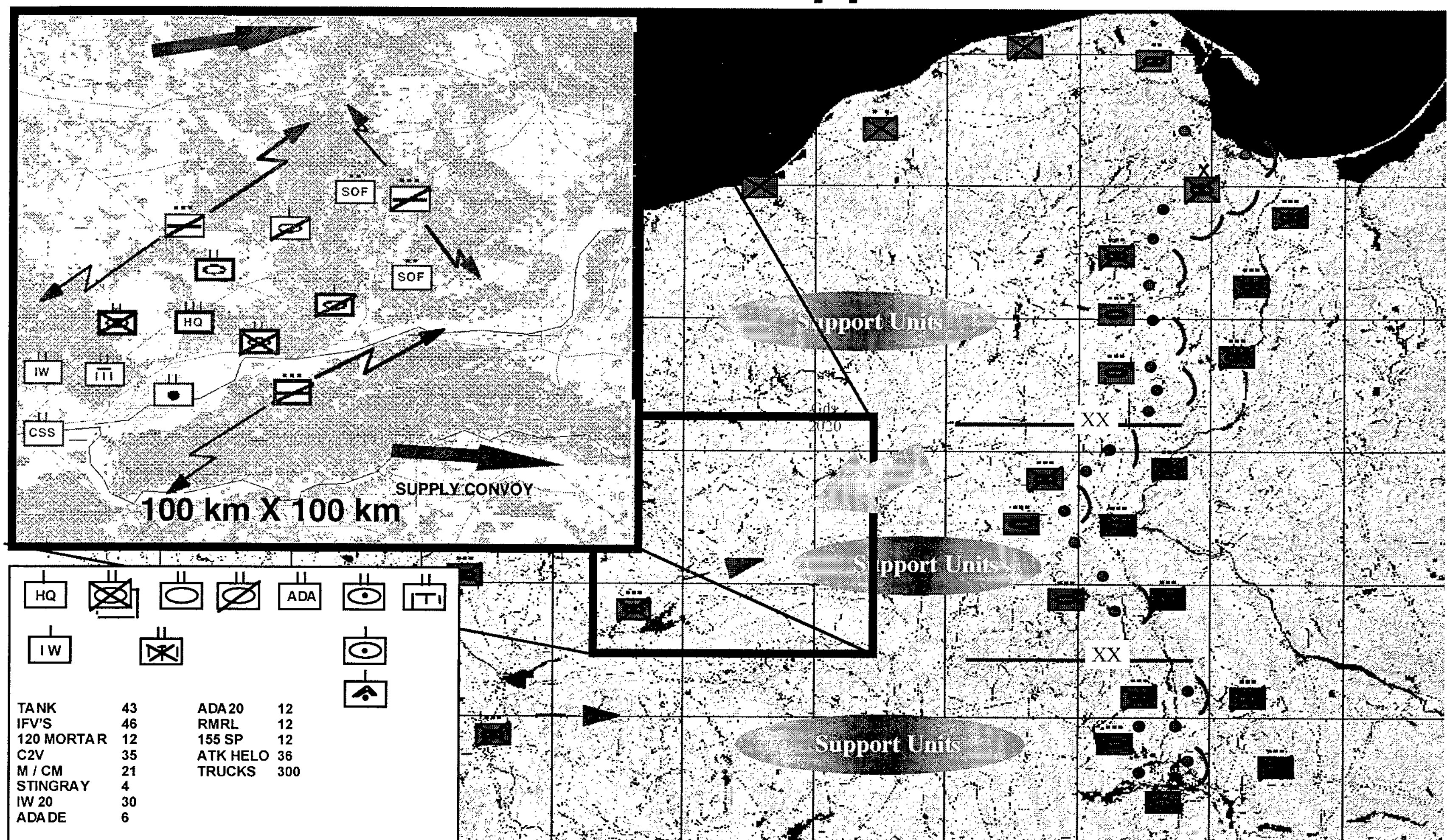
The intent was to start with a very stressing case, assess what Blue force losses would be with different technologies and/or TTPs, and then parametrically reduce the ADA threat until insertion losses became small (< 10 percent). The combat radius capability of the advanced airframe (AAF) is in excess of 1,000 kilometers. We chose a specific subsection of the mission that will expose the aircraft to enemy ADA. We knowingly limited the exposure time and distance, due to limitations in the available geographical data.

Objectives and Strategy Assumed for Analysis

- **Friendly force objectives: quickly stop enemy advance, attack operational and strategic centers of gravity, and disintegrate the enemy's will to fight**
- **U.S. application of joint force**
  - **Establish theater defenses, support allies with liaison teams, conduct SEAD, etc.**
  - **Apply variety of long-range fires immediately**
  - **Attack into enemy's rear almost immediately to break his momentum, destroy an operational center of gravity, his second-echelon operations**

The general strategy for how we might use joint forces in the vertical envelopment period is shown in this chart. Critical to any vertical envelopment analysis is the understanding of how the other component-level forces will be participating in this mission. As we will discuss in the next two sections, the roles of the Air Force and Navy in the area of suppression of enemy air defenses (SEAD) and joint fires will be critical to the vertical envelopment battle force's success. Similarly, these two services' ability to transport the battle force into the theater will be critical to the success of the vertical envelopment concept.

U.S. Mission: Deny Enemy's Ability to Form "Critical Mass" to Support Advance



GENERAL SCENARIO

An enemy has invaded a U.S. ally and U.S. forces are mobilized and poised to enter the fray approximately one week after the onset of hostilities. During the first week of battle, invading forces have managed to advance approximately 200 kilometers, overwhelming initial allied forces' attempts to prevent the invasion. Allied forces have temporarily achieved a halt of the invading forces across a broad forward line of troops (FLOT), as depicted in the graphic on page 15. Gridline spacing is 50 kilometers. The invading forces, low on fuel and ammunition, have assumed a hasty defensive posture waiting for their operational reserve to reach the FLOT and punch through the fragile allied defenses. The operational reserve is made up of a heavy, elite division advancing with one brigade up and two brigades back, trailed by sufficient logistics, in the form of fuel and ammunition, to reestablish momentum after reaching the FLOT. The enemy commander has secured his rear area with lighter infantry units along the northern, sea approach, protecting against an amphibious assault on his flank, and has bolstered his rear area and main supply route (MSR) defenses with state-of-the-art air defenses ranging from advanced gun-missile combination (2S6), short-range, low-altitude systems to long-range, high-altitude systems such as the SA-17 and SA-12, protecting against airborne and air-mobile assaults.

The vignette chosen for analysis pits a U.S. battle unit against the elite heavy division. The battle unit's mission is to disrupt, delay, or destroy this division. The battle unit will be air inserted into ambush positions in front of the advancing division.

The battle unit selected for analysis in this scenario was one of six battle units in the force under analysis by TRADOC. The other battle units attacked from the the flanks and the rear. Due to limited time and model constraints, we chose to model only one of the units being air inserted. The other battle units are an integral part of TRADOC's AAN concept and must be modeled in any analysis of the ground combat phase.

Outline

- **Methodology**
- **Scenario**
- **Air maneuver phase**
- **Ground combat phase**
- **Insights**

We now discuss the analysis performed on the air maneuver phase of the air-mech concept.

Focus of Air Maneuver Phase

Perform initial study examining potential for successful insertion of vertical envelopment force in high-intensity threat environment

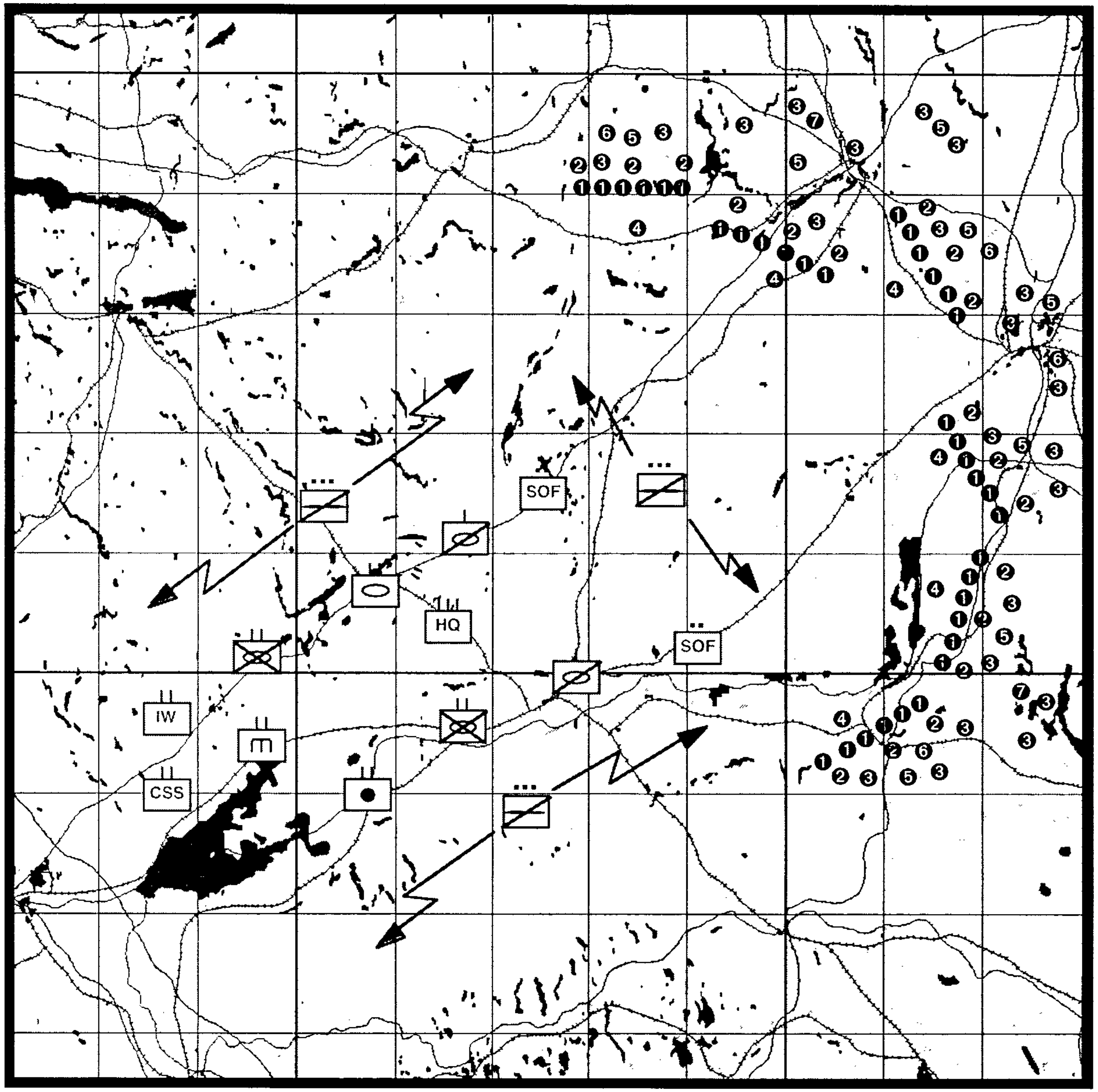
A critical capability for the U.S. battle unit is that of self-deployability. To accomplish its assigned mission, the battle unit must fly into the enemy rear area to interdict the operational reserve by means of disruption, delay, or destruction. The focus of this phase of the analysis was to examine the capability of the AAF to insert the battle unit's ground forces into the enemy rear area under different assumptions and conditions.

Air Maneuver Analysis Plan

- **Employ early entry scenario with deep insertion "air maneuver" phase**
- **Create challenging threat IADS environment (laydown, capabilities, and tactics)**
- **Use CAGIS, RJARS, and CHAMP to parametrically explore AAF survivability**
- **Present mission to experienced helicopter pilots**
  - **Start with low Intel case first, move through to medium and high Intel, along with necessary planning**
  - **Vary flight profile, signature, level of SEAD, countermeasures**

The methodology used to conduct this analysis can be described in the following steps:

1. Decide where the U.S. battle unit must be inserted in order to successfully accomplish its mission.
2. Establish a detailed (item-level) laydown for the enemy's integrated air defense (IAD) network in the theater's area of interest defined above (air-to-air threats were not considered to be part of the IAD for this effort). Use CAGIS to evaluate resulting radar coverage. Note enemy air was not modeled.
3. Establish varying levels of intelligence (Intel) to be presented to the aviators prior to mission planning. Present this information to aviators on an integrated CAGIS map display.
4. Establish varying flight profiles based on signature, SEAD and countermeasures assumed. Load the associated data into RJARS.
5. Have experienced aviators fly flight paths for each of the AAFs using the CHAMP flight planner.
6. Conduct parametric analysis by flying each of the sets of flight paths in RJARS to determine aircraft survivability and critical components of the mission.



AIR-MECH BATTLE UNIT INSERTION

ICON	CARGO	# LIFTERS
1	AFV	36
2	ARES	18
3	AC2V	22
4	ARV	6
5	AFSV	8
6	AFSS	4
7	UAV	2

ICONS REPRESENT LZs FOR LIFTERS ON INSERTION OF BATTLE UNIT.

The graphic on page 20 depicts the battle unit insertion. These landing zones were chosen assuming minimal subsequent movement by ground vehicles once disembarked from AAFs.* Eighty-four aircraft are required to transport the battle force.

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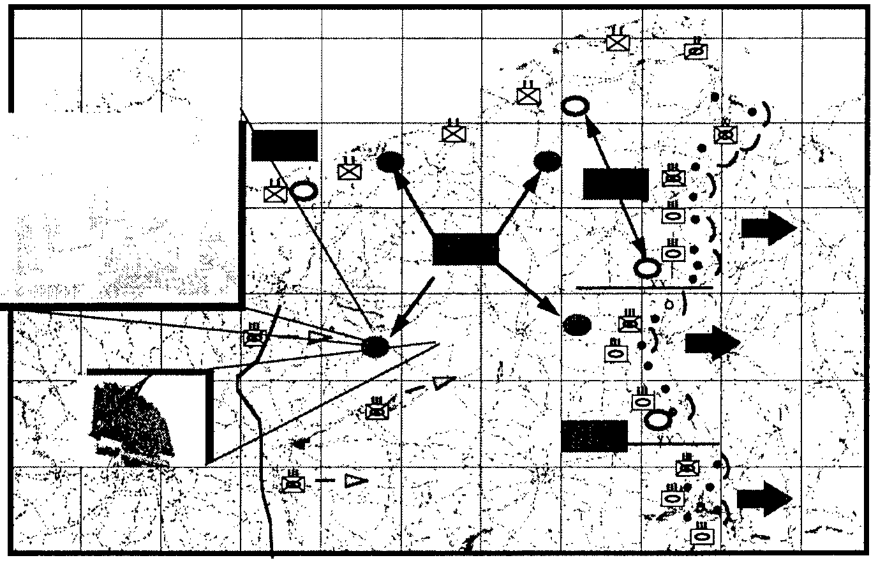
*Scenario assumed vertical insertion of the forces close to their planned fighting positions. The landing sites were also selected to be in an area not covered by enemy air defense. The assumption that safe and tactically significant landing sites can always be found may not always be true. This is a best-case scenario, and it was selected to separate the ground combat issues from the air-insertion analysis effort. Other scenarios have the forces maneuvering to the battle sites after being inserted.

An Integrated Air Defense Network Is One of the Enemy's Moderate-Cost Highly Effective Combat Multipliers



The quantity and quality of enemy air defenses can have a very significant impact on the viability of the air-mech (or other) vertical envelopment concept. The Defense Intelligence Agency and the National Ground Intelligence Center were consulted on worldwide trends in air defense systems. Based on their very helpful input, RAND constructed a hypothetical air defense system that would be covering an advancing enemy army. The air defenses depicted in this scenario are intended to represent a "high-end" opponent of the 2020 era. Today, the Russian army is capable of fielding the type of air defense system depicted in this research. In coming years, other armies may be able to employ similar integrated air defense systems.

The enemy air defenses are allocated by echelon. In this chart we show the corps-level long-range, high-altitude defenses represented by the SA-12 and SA-17 batteries. It was assumed that the enemy corps depicted on the map (which is in charge of the enemy's main effort; other forces are off-map to the south and west) would be accompanied by two battalions (total of six batteries) of SA-12s and two battalions (also six batteries) of SA-17s. By the time this vignette takes place, we assume that each battalion has already lost one battery due to U.S. and allied SEAD.

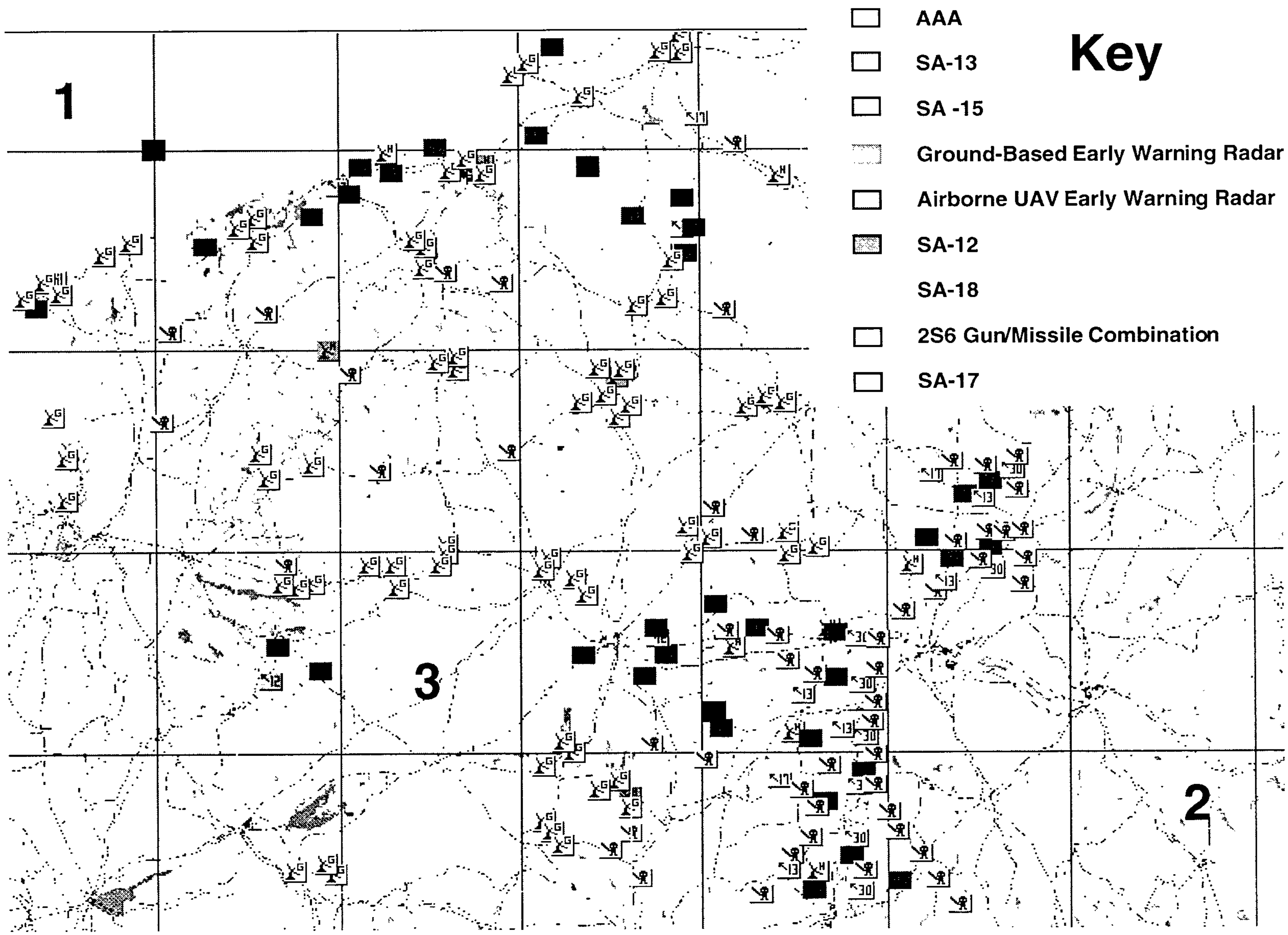
Composition of Enemy (Division and Below) Air Defense Assets

System type	2020 (AAN Spring Wargame)	2020 TO&E *(DIA-NGIC)*	Systems employed
SA-15	34–66	12	9
2S6/SA-19	18–24	28	12
SA-18	111–132	72	48
SA-13	18–24	0	6

Next we estimated the air defenses organic to the divisions themselves. These are summarized above. Quantities and types of organic divisional systems were derived from various literature searches, together with input from the Defense Intelligence Agency (DIA) and National Ground Intelligence Center (NGIC) on the quantity of systems that regional opponents could have by the 2020 period. Again, we have assumed that the enemy's divisional air defenses have suffered losses by the time the vignette takes place. The divisions along the FLOT are assumed to be at roughly 75 percent strength in air defense systems when the vignette starts.

RAND estimates that enemy 2020-type divisions along the FLOT were armed with considerably fewer SA-15s, SA-18s, and SA-13s than were played in the 1998 AAN Spring Wargame. Our goal was to challenge the vertical insertion with an air defense that many countries could afford and operate in the 2020 time frame. This, we believe, would be the most likely scenario for the first employment of the vertical envelopment concept.

Locations of Enemy Air Defense Systems



Two tiers of enemy air defense were instituted in the scenario, pictured on page 24.

The lower-quality ADA units are along the coast. As the enemy force advanced into the territory of the U.S. ally, lower-quality units (truck-mounted infantry, for example) were deployed along the coast to protect it against a flanking amphibious assault. These units have considerably fewer air defense systems than the divisions along the FLOT. Anti-aircraft artillery (AAA) have been substituted for 2S6, and there are far fewer SA-18 man-portable air defense systems (MANPADS) in the units in the north. Gridline spacing is 50 kilometers.

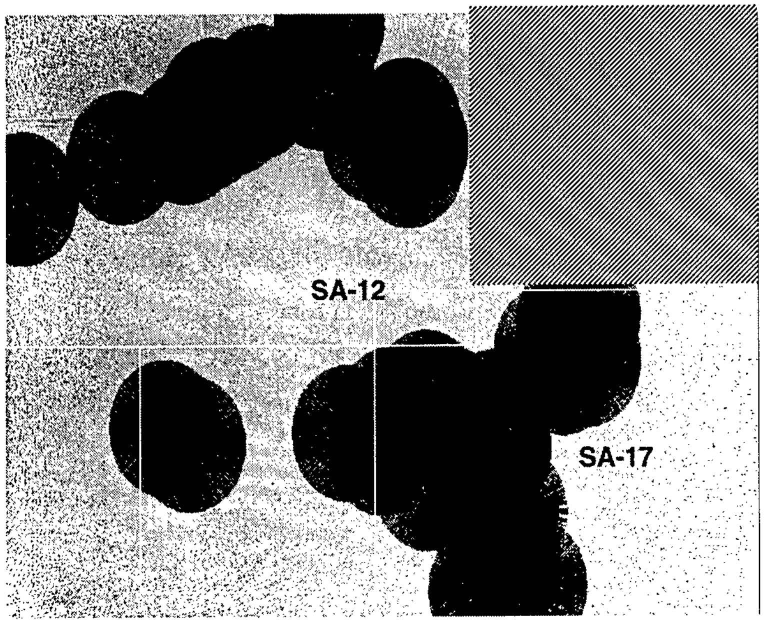
The figure depicts the detailed, integrated air defense laydown created in RJARS for this analysis. The defense is partitioned into three sections for analysis:

1. Upper left quadrangle: northern sea air approach
2. Lower right quadrangle: eastern cross-FLOT air approach
3. Lower west–central quadrangle: ground combat zone modeled in JANUS

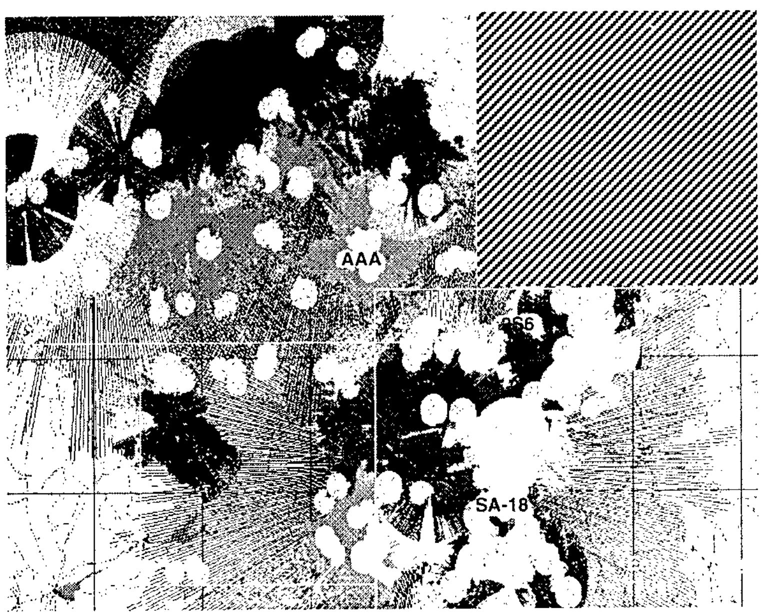
Each of these areas was examined separately.

The upper right quadrangle (covered by the key in the figure) was not considered as an air approach for analysis because of the extreme distances that insertion aircraft would have to traverse, and because it was assumed to be populated by air defenses of an adjoining enemy unit (not shown).

High-Altitude Enemy Air Defense Coverage



Low-Altitude Enemy Air Defense Coverage



The top figure on page 26 depicts the radar coverage provided by medium- and high-altitude air defense radars. The fans drawn represent line-of-sight (LOS) weapons ranges for each of the three types of radar-guided surface-to-air missiles (SAMs) included here. The LOS fans were calculated for altitudes in excess of 20,000 feet. The various air defense radar fans are represented as follows:

Dark gray: SA-15 radars

Mottled gray: SA-12 radars

Striated light gray: SA-17 radars

(For a full-color version of this and other charts, along with more extensive description, please see the on-line version of this document at *http://www.rand.org/publications/DB/DB321/.)*

The total coverage of the area by radio-frequency (RF) SAMs, at this altitude, will cause significant challenges for any aircraft. DIA and NGIC believe this will be standard coverage for many potential regional adversaries in the AAN time frame.

Additional SEAD, and other radar countermeasures, will be required for any vertical envelopment aircraft flying at this altitude. Taking out individual radars should have limited impact, because of the integrated architecture used by the enemy. This points out the need for new TTPs based on the increased levels of situational awareness available in the AAN time frame.

The bottom figure on page 26 depicts the weapons coverage of the enemy's low-altitude systems, specifically against a nonstealthy aircraft operating at 100 feet above ground level. Note that there are a large number of enemy systems capable of engaging aircraft at this altitude. Small white circles represent pairs of 30mm anti-aircraft guns, small light gray circles are SA-18 MANPADS and 2S6 self-propelled gun/missile systems, and mottled gray portions are SA-13. Note how the range fans of SA-12, 15, and 17 are all much smaller than that shown in the previous diagram (medium-/ high-altitude coverage). Not shown on this diagram is the threat posed by weapons such as tank

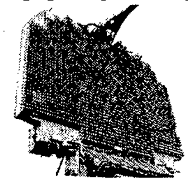
main guns, wire-guided missiles, and heavy machine guns, all of which are capable of engaging (under certain conditions) low-altitude aircraft.

The figure shows that the enemy ADA does not have complete coverage of the area of operation. There are areas that have radar coverage but no weapons capable of engaging the aircraft.

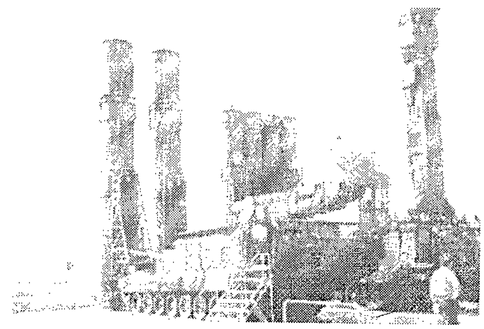
SA-12 Is a Tactical SAM Which Can Engage Both Aircraft and Missiles

SA-12 characteristics

- **Surveillance radar range: 250 km**
- **Sector scanning radar range: 175 km**
- **Missile guidance radar range: 150 km**
- **Target radar cross section: 2 sq. m**
- **Missile max. range: 100 km (Gladiator) 200+ km (Giant)**
- **Missile min. range: 6 km**



Surveillance radar



TELAR

SOURCE: ***Jane's 1998–1999 Land-Based Air Defence***

To better understand the severity of the ADA problem for vertical envelopment, we now present a short description of each of the systems. All the data presented are from Jane's 1998–1999 land-based air defence book. These are the advertised capabilities of the systems. Real capabilities in 2020–2030 may be different. Vertical envelopment concepts should, as a starting point, be able to deal with current high-end ADA systems.

The SA-12 has the ability to acquire and engage targets at 100-mile-plus ranges. Like many high-end systems, it has a very capable radar and missiles with high flyout speed and good altitude capabilities. This does not mean that the SA-12 is invincible, but considerable research and development of equipment and concepts for dealing with this system will be needed for the air-mech concept to be successful.

SA-17s and SA-15s Are Primarily Designed to Defend Against Close Air Support

SA-17 characteristics

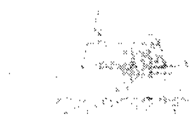
- 160 km detection range
- 120 km acquisition range
- Effective against targets at 15 to 25,000 m altitudes
- Missile range: 50 km

SA-15 characteristics

- 25 km Doppler radar
- Effective against targets at 10 to 6,000 m altitudes
- Missile range: 1.5 to 12 km

SA-17

SA-15



SOURCE: *Jane's 1998–1999 Land-Based Air Defence*

The SA-17 fills the gap between short- and long-range ADA systems. It is readily transportable and will pose tactical problems for vertical envelopment. Like the SA-12, technical and operational techniques need to be developed to deal with this threat.

The SA-15 is an extremely mobile short-range ADA system. Its radar has shorter detection ranges than the SA-17's. The large number of SA-15s in the battlefield will, however, challenge the Blue force aircraft flying in enemy-controlled airspace.

Low-Altitude Systems Tend to Have Smaller Engagement Envelopes

2S6 tracked AD unit

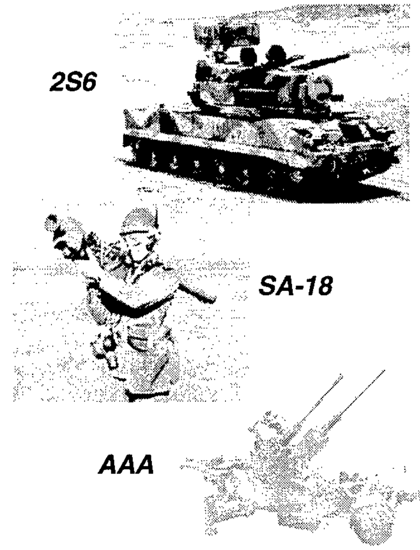
- **30mm (4) radar directed**
- **SA-19 missile**

SA-18 MANPAD

- **Effective against targets at 10 to 3,500 m altitudes**
- **Missile range: 0.5 to 5.2 km**

AAA

- **30mm optically directed**
- **3–4 km engagement range**

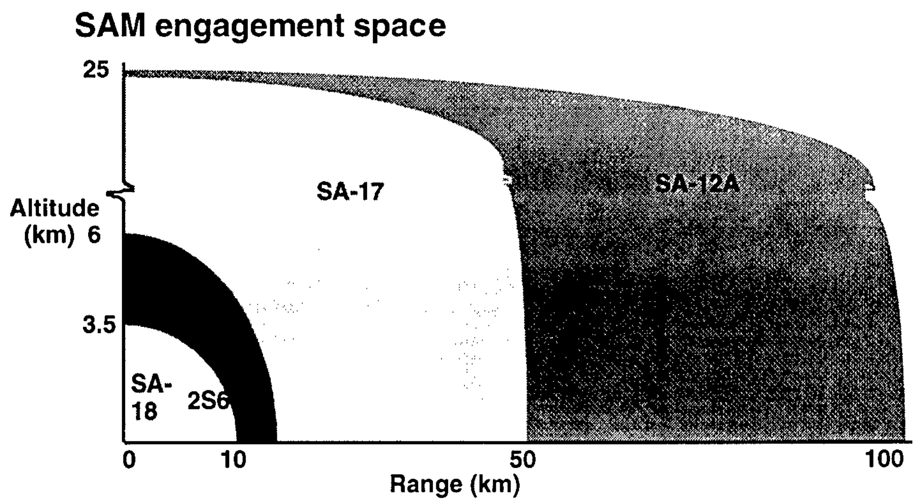


SOURCE: ***Jane's 1998–1999 Land-Based Air Defence***

Lastly we present data on short-range ADA systems. Of critical concern is the ability of these systems to operate in the nonemitting mode, i.e., using thermal sensors or optically guided. Along with small arms fire and tank rounds, these systems represent the limiting ADA case when RF systems have been suppressed.

Infrared and optical countermeasures need to be developed to deal with these systems.

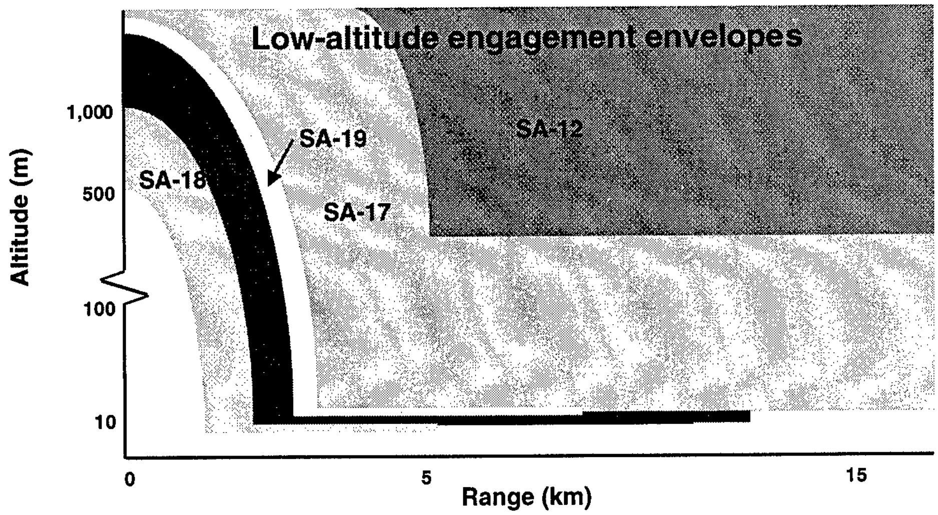
High-End SAMs Have Comparatively Larger Envelopes (both Altitude and Range)



SOURCE: *Jane's 1998–1999 Land-Based Air Defence*

This figure shows the difficulty of flying above long-range SAM systems. Effective suppression of SA-12s and SA-17s will be required for Blue force aircraft to operate at medium altitudes in this environment.

However, High-End SAMs Have Critical Limitations as Well



SOURCE: *Jane's 1998–1999 Land-Based Air Defence*

This chart demonstrates one of the weaknesses of the medium- and high-altitude SAMs. Jane's lists the SA-12's minimum engagement altitude as 200 meters. Close-in, very-low-flying aircraft are relatively unaffected by these SAM systems. The low-flying aircraft will, however, be exposed to low-altitude SAMs, such as the SA-15 and SA-18. Using countermeasures and flight tactics can potentially minimize losses from these systems. Current versions of the SA-10d can engage helicopters at a 10-meter altitude (Jane's). We therefore assume the SA-12 will be developed with lower engagement altitude capabilities by 2020 in our model.

Key Assumptions Made for Our Analysis

- **Tilt-rotor data is valid**
  - **Relatively large airframe (both fuselage and rotors)**
  - **RCS and IR signature levels roughly twice that of V-22**
- **Mission occurs during daytime, good weather**
- **Flight profiles were created by RAND analysts and Navy and Army aviators**
- **84 aircraft flown, half from east and half from north (over water), in tight formation in trail**
- **Enemy AD assumed to operate in autonomous C2 mode (minimal integration)**
- **MANPADS and AAA positions not known prior to mission**
- **Tanks and small arms fire not modeled**
- **IRCM effectiveness estimated from current IRCM and CCM technology trends**

The Advanced Air Frame modeled in CHAMP and RJARS for this analysis was a relatively large fuselage and employed tilt-wing technology. The data input to the simulations was developed by RAND in coordination with the U.S. Army Research Laboratory (ARL) and represent a projection of current technology to the time frame of the scenario. The projections used were consistent with applicable physical laws. The signature (RCS* and IR) data for the AAF was approximately twice that of the V-22 Osprey.

All optical sights were assumed to have night-vision devices, resulting in equal day and night performance of the sights. While the air insertion took place during daylight hours with good weather, the results would be similar for a night-time mission given the enemy's night-vision capability.

For the first "baseline" set of runs a total of 84 aircraft were inserted, with 42 utilizing the northern, sea air approach and 42 utilizing the eastern, land air approach. The aircraft were flown in a tight trail formation at approximately 200 feet in altitude, at a speed of approximately 240 knots.

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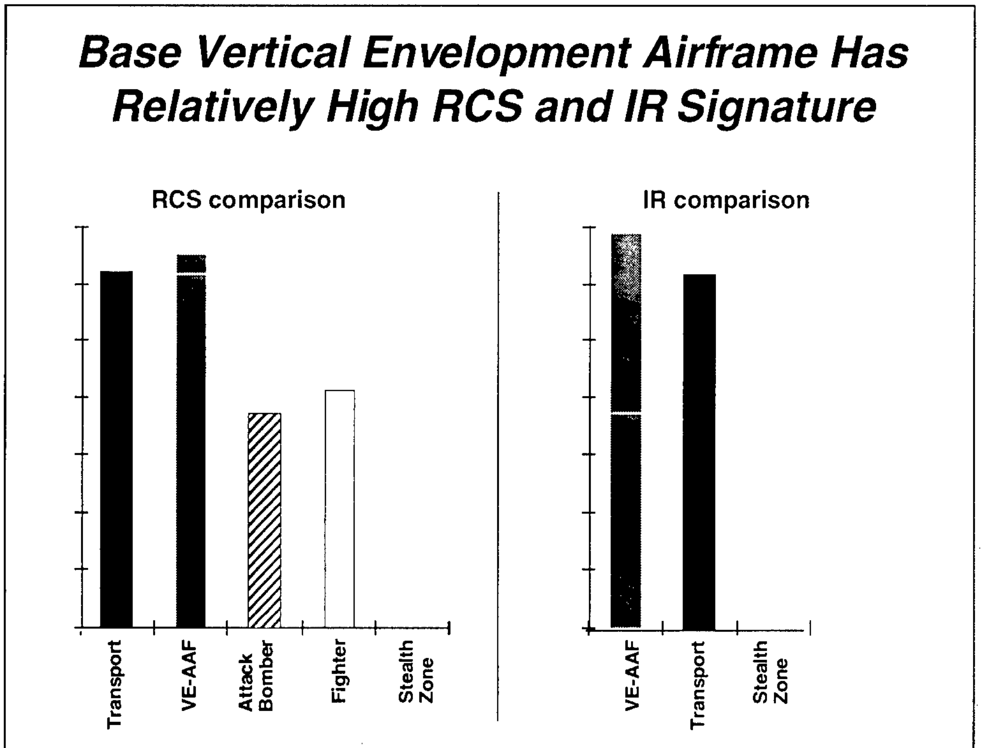
*RCS is radar cross-section.

The air defense network radars and C2 network provided early warning to individual air defense assets operating in a weapons free–autonomous mode.

For the high-situational-awareness case, aviators were given locations of all threats with the exception of MANPADS (SA-18s) and AAA.

Neither tank main guns nor small arms fire were modeled as threats.

IR countermeasure effectiveness was projected to the scenario time frame based on current technology trends. Counter-countermeasures were also incorporated in the missiles.



The chart illustrates the relative signatures of the modeled AAF when compared to several other types of aircraft.* The RCS comparisons are logarithmic (DBSM), while the thermal are linear (degrees centigrade).

Discussions with the Army aerodynamics engineers researching vertical envelopment tilt-rotor signature issues led to the estimate that the vertical envelopment tilt-rotor transports' optical, IR, and RF signatures could be modeled as twice that of a multi-engine transport plane.

Transport aircraft are generally not designed to be stealthy. To explore the potential effects of stealth, we postulated that a prop-driven transport could have the signature characteristics of a low-observable (LO) aircraft. The LO aircraft RF and IR signatures are very low compared to the nonstealth aircraft, and do not appear on the same scale in this graph.

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*Radar data from Fred E. Nathanson, *Radar Design Principles*, New York: McGraw-Hill, 1969, and Rebecca Grant, *The Radar Game*, Arlington, VA: IRIS, 1998. Thermal data from Richard D. Hudson, Jr., *Infrared System Engineering*, New York: John Wiley and Sons, 1969.

Key Parameters Explored in Air Maneuver Phase of Analysis

- **Flight paths: different operators**
  - **Ingress/egress *locations* and *formations* for airlifters**
  - **Airlifter mobility performance attributes (speed and altitude)**
- **Level of situational awareness provided**
- **Level of enemy air defenses active in simulation (due to SEAD)**
- **Airlifter thermal and visual signatures (parametric reduction in simulation)**

The analysis entailed varying several key parameters expected to have a significant impact on mission outcome.

Each set of aviators generated flight paths based on a given amount of situational awareness (SA) and a specific set of flight tactics. We then varied the level of SEAD and the aircraft's IR and RF signatures in the RJARS model. Each case was run between 10 and 20 times. RJARS results for overall kills were the same for each case, though in several cases the number killed by a specific weapon system changed (for example, one run might have 6 kills by AAA and 7 by SA-18s, the next run might have 5 kills by AAA and 8 by SA-18s).

Variety of Flight Path Locations and Profiles Were Considered in Air Maneuver Analysis

Flight path	Path profile	Path creator
Baseline	200 ft AGL/240 kts	RAND analyst
Low & slow	50 ft AGL/60 kts	RAND analyst
Low & fast	70 ft AGL/200 kts	Navy helo pilot
Very low & slow	20 ft AGL/100 kts	Army helo pilot
Medium altitude	20,000 ft AGL/330 kts	Navy pilot

The aviators who flew the flight paths were a mixed group of RAND analysts and Navy and Army aviators. The run sequence was based on the availability of aviators. The set of flight paths generated enabled RAND to explore a large range of parameters, as discussed in the next chart.

Excursions Examined in Simulation

Flight path description/ creator	Parameters examined											
	Medium-level SA						High-level SA					
	No SEAD		Medium SEAD		High-level SEAD		No SEAD		Medium SEAD		High-level SEAD	
	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig
Baseline/ RAND analyst	√	√			√	√						
Low & slow/ RAND analyst	√	√			√	√	√	√	√	√	√	√
Low & fast/ Navy pilot							√	√	√	√	√	√
Very low & slow/ Army pilot											√	√
Medium altitude/ Navy pilot							√		√			

DEFINITIONS: Medium-level SA provides Intel on 50% of SAMs (type and location); high-level provides 100% Intel. No SEAD means all AD units active; medium SEAD means SA-12s, SA-17s removed; high-level SEAD means SA-12s, SA-17s, SA-15s, and 2S6s removed. Base signature corresponds to AAF; LO signature corresponds to the level of a notional low-observable helicopter.
Blank space means specific case was not examined.

The chart shows which excursions were examined during the conduct of the analysis. Where possible, we attempted to test either end of the envelope for each parameter first, before delving into the middle ground where arriving at a point solution would be difficult at best. Rather, we were trying to draw more general conclusions about which parameters dominated the outcomes. For example, for the medium-level SA excursions, we examined first the baseline and LO signature cases without SEAD and with a high level of SEAD, and determined from those outcomes that the medium-level SEAD cases could offer no added value to the analysis.

Similarly, in the high-level SA excursions, we examined the baseline signature cases without SEAD and medium-level SEAD first, and from these results determined that the high-level SEAD case could provide no additional value to the analysis.

It is important to note this is a parametric analysis. We do not propose that the Army consider missions over well-defended enemy territory with insufficient situational awareness and no SEAD. The analysis, however, was intended to give insights on what levels of SA, SEAD, and stealth are needed to conduct a successful air insertion mission. These aspects are discussed in the next slide.

Summary of Results: Percent of Vertical Envelopment AAFs Surviving Mission

Flight path description/ creator	Parameters examined											
	Medium-level SA						High-level SA					
	No SEAD		Medium SEAD		High-level SEAD		No SEAD		Medium SEAD		High-level SEAD	
	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig	Base sig	LO sig
Baseline/ RAND analyst	0%	0%			0%	25%						
Low & slow/ RAND analyst*	40%	57%			93%	98%	62%	79%	79%	88%	93%	100%
Low & fast/ Navy pilot							19%	63%	56%	87%	56%	87%
Very low & slow/ Army pilot											62%	87%
Medium altitude/ Navy pilot							0%		100%			

DEFINITIONS: Medium-level SA provides Intel on 50% of SAMs (type and location); high-level provides 100% Intel. No SEAD means all AD units active; medium SEAD means SA-12s, SA-17s removed; high-level SEAD means SA-12s, SA-17s, SA-15s, and 2S6s removed.
Base signature corresponds to AAF; LO signature corresponds to notional level of stealth.
* Over-water-only cases.

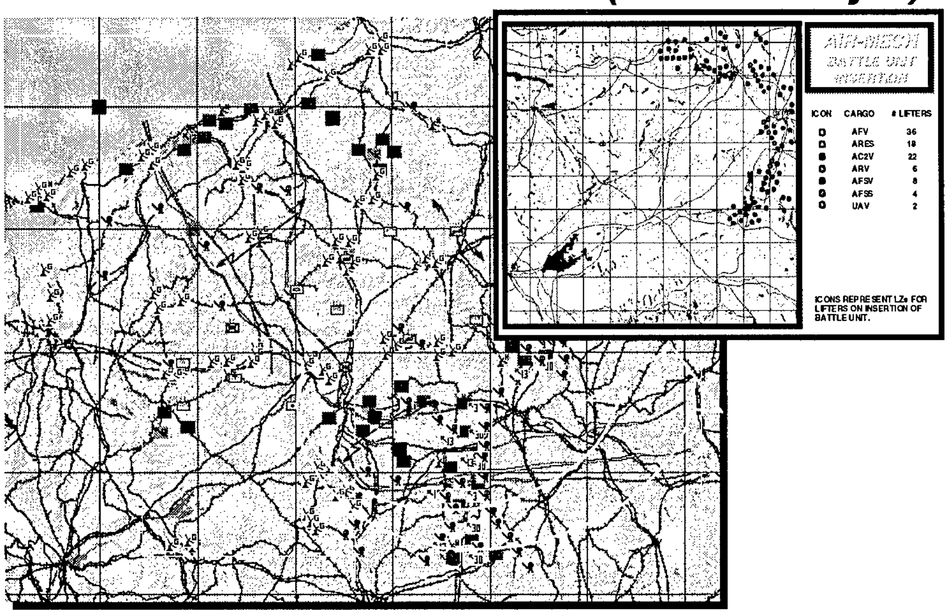
A total of 24 excursions were examined during the course of the analysis. A cursory examination of the results yields the following general conclusions:

1. Greater SA significantly improves mission survivability.
2. SEAD is effective when used with increased SA and/or stealth.
3. Stealth by itself improves survivability.
4. Stealth, SA, and SEAD by themselves do not lead to acceptable mission survivability rates.
5. Combinations of stealth, SA, SEAD, and flight tactics can result in successful missions.

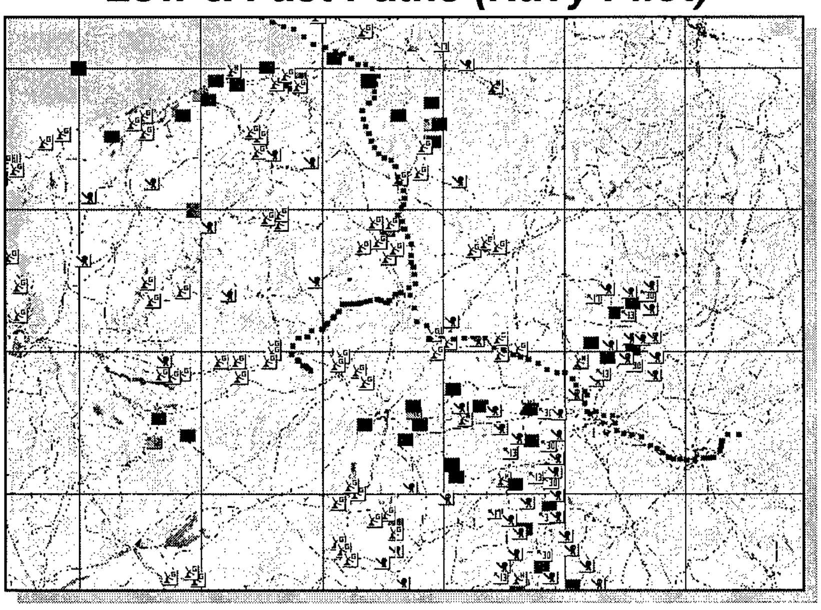
It is important to note again that we are not suggesting Army aviators would or should conduct any of the high-loss missions. The analysis they would conduct in the mission-planning phase would identify the high loss rate and the mission would, in most cases, not be flown, or significantly lower-loss flight paths would be proposed.

None of the observations are counterintuitive, and the results do demonstrate a consistency across all of the excursions. Further examination of the excursions, grouped by flight profile, was warranted. These results are shown in the following charts, beginning with a description of the flight profiles for the first group (RAND analyst).

Locations of Baseline Paths (RAND Analyst)



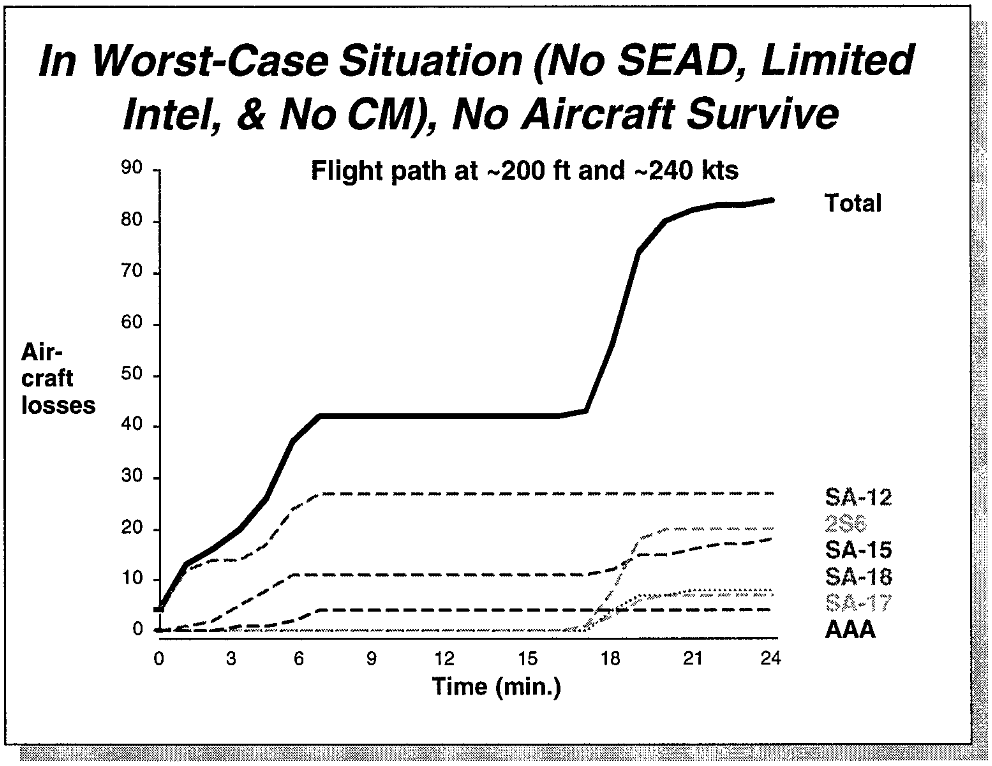
Low & Fast Paths (Navy Pilot)



The top image on page 41 depicts the baseline flight paths flown by RAND analysts. The flight paths were developed based on the ground force (battle unit) maneuver plan (insert).

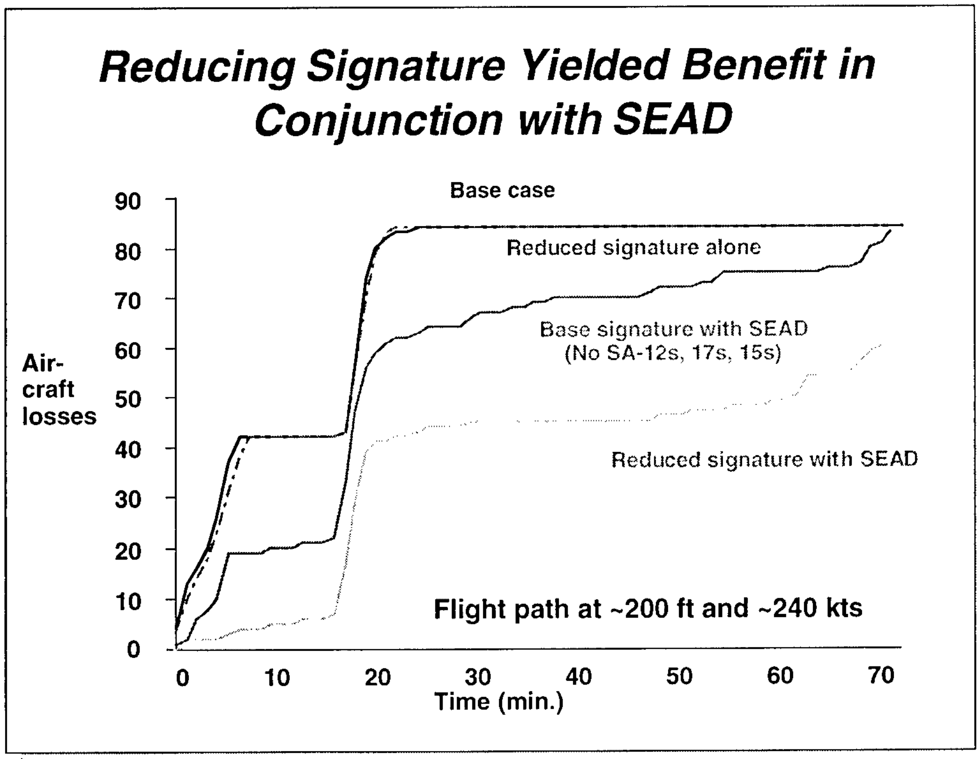
Each flight path represents paths for six advanced airframes ingressing in a tight (~50 meter interval) trail formation.

All the airframes are flown in simultaneously on each approach route.



An examination of the attrition of the airframes over time, and by air defense system, reveals that the SA-12 is the most dangerous threat to the airframes, followed closely by the 2S6 and the SA-15.

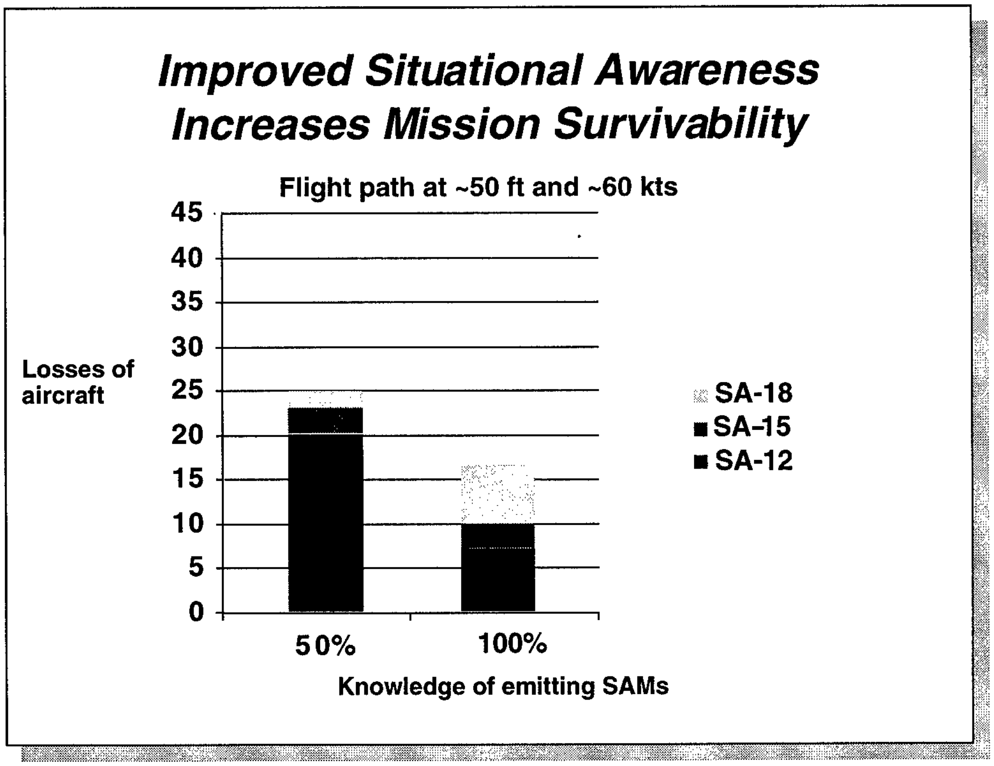
The two approaches led to the aircraft being exposed to different ADA systems. The aircraft flying in from the ocean were well within the range of an SA-12 and several SA-15s prior to landfall. Roughly 90 percent of the aircraft were destroyed before they traveled 10 kilometers in from the coast. SA-15s killed the rest as they progressed inland. The aircraft flying east across the FLOT were later shot down by a combination of 2S6s, SA-15s, SA-17s, and SA-18s. The 2S6s killed roughly half of the vertical envelopment tilt-rotor transports flying cross-FLOT.



Running the baseline case with Comanche (indicated by "reduced signature" in the chart) did not change overall mission survivability. This was due to the SAM radars still being able to pick up the Comanche. The target acquisition ranges were primarily limited by the terrain and not the radar signature of the aircraft. In both cases (tilt-rotors and Comanche), RF SAM kills occurred at ranges significantly less than the RF missiles' maximum ranges, due to the low altitude at which the aircraft were flying.

Increasing the amount of SEAD did not change overall mission survivability. The tilt-rotors did, however, survive for a longer period. Again, we used a best-case scenario (a Comanche-like aircraft) to bound the problem. In this case, SEAD was able to take out all SA-12s, 15s, and 17s. While this is not realistic for the entire theater of operations, it may be possible to clear several flight corridors. From an aviation tactics standpoint, all known SAM sites along the flight path would have to be suppressed to make the mission a "go." We note that even in this case, mission success is not guaranteed. Additional tactics and technology are needed.

Combining aggressive SEAD and stealthy aircraft enabled some aircraft to survive the mission. While the attrition rate was high, the concept of using multiple survivable enhancement techniques clearly had merit.



When we examined the outcomes of excursions grouped by various SA levels, we noted that increased SA reduced the effectiveness of the emitting SAMs. In this case we examined only the group of aircraft flying in from the ocean. The pilot was instructed to fly around or under all RF SAM sites that appeared on the flight planning aid (CHAMP).

The limited aerodynamics of the tilt-rotor led to some SA-12 kills, even when the pilot knew where all the SA-12s were. Two SA-12 missile sites could not be totally avoided by the tilt-rotors. The SA-12's target acquisition radar can detect a two-square-meter aircraft at over 250 kilometers. SA-12 missiles can engage targets at 100 kilometers.

It is therefore not surprising that over a 250-kilometer path traversing enemy-held terrain, surviving SA-12s have multiple opportunities to engage the vertical envelopment tilt-rotors.

Improved Intelligence, SEAD, Stealth, and Low-Altitude Paths Enhance Mission Survivability*

	Blue Aircraft Lost			
AD System	No SEAD	No SA-12, 17	No SA-12, 15, 17	No SA-12, 15, 17, Stealth
SA-12	6	0	0	0
SA-17	0	0	0	0
SA-15	3	5	0	0
SA-18	7	4	5	0
2S6	0	0	0	0
AAA	0	0	0	0
Total	16	9	5	0

*42 tilt-rotors flying in from the ocean

The next series of runs examined the effects of variable levels of SEAD. When the SA-12s, 15s, and 17s are suppressed, mission survivability is significantly increased. The SA-12 and SA-17 are not easily jammed and will, therefore, require aggressive SEAD. SA-15s can potentially be jammed, but enemy tactics and improved versions of the SA-15 could make jamming of the missile more difficult. A jammer can also be used by the enemy as a beacon for RF home-on-jam missiles and/or improved SA for optically guided ADA such as AAA and IR SAMs. Other ADA assets such as the 2S6 will switch to the AAA mode when jammed. There were very few non-RF ADA systems defending the coastline (this was purposely designed), and as the table shows of these systems, only the SA-18s successfully engaged the vertical envelopment tilt-rotor force.

Use of stealth further increases mission survivability. The lower IR signature of the aircraft led to no SA-18 losses. The use of very good situational awareness, effective SEAD, and stealthy aircraft makes this type of mission look feasible. The main challenge would be to locate the majority of enemy active and passive air defense systems as the mission was being planned, and then get continuous real-time updates while the aircraft are in flight.

Two problems were noted in this approach. First, the flight speed was very slow, less than 60 knots. The vertical envelopment ground vehicles could likely drive to the landing site in a comparable amount of time. Second, the ADA environment was relatively free of optical ADA systems, not expected in a mission flying over a front-line enemy division (cross-FLOT).

One possible tactic is to fly fast and minimize the exposure time to enemy ADA. We modeled this tactic for both the ocean approach and the cross-FLOT mission. (See bottom image on page 41.)

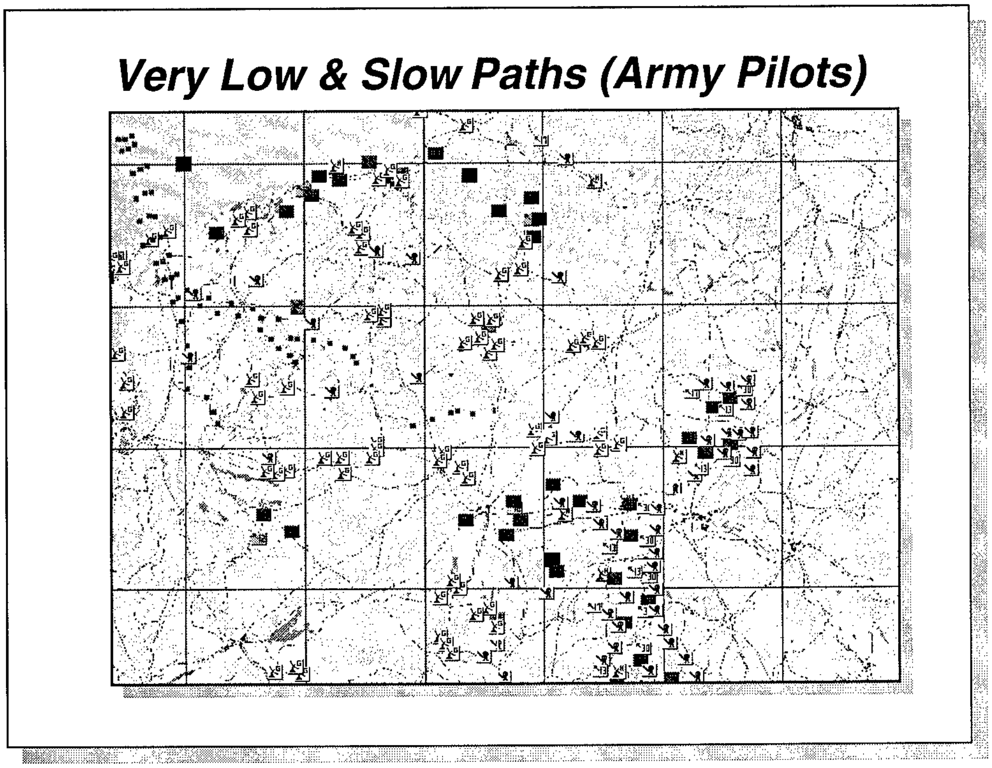
Cross-FLOT Mission Survivability with Low Altitude, SEAD, and Stealth Is Low*

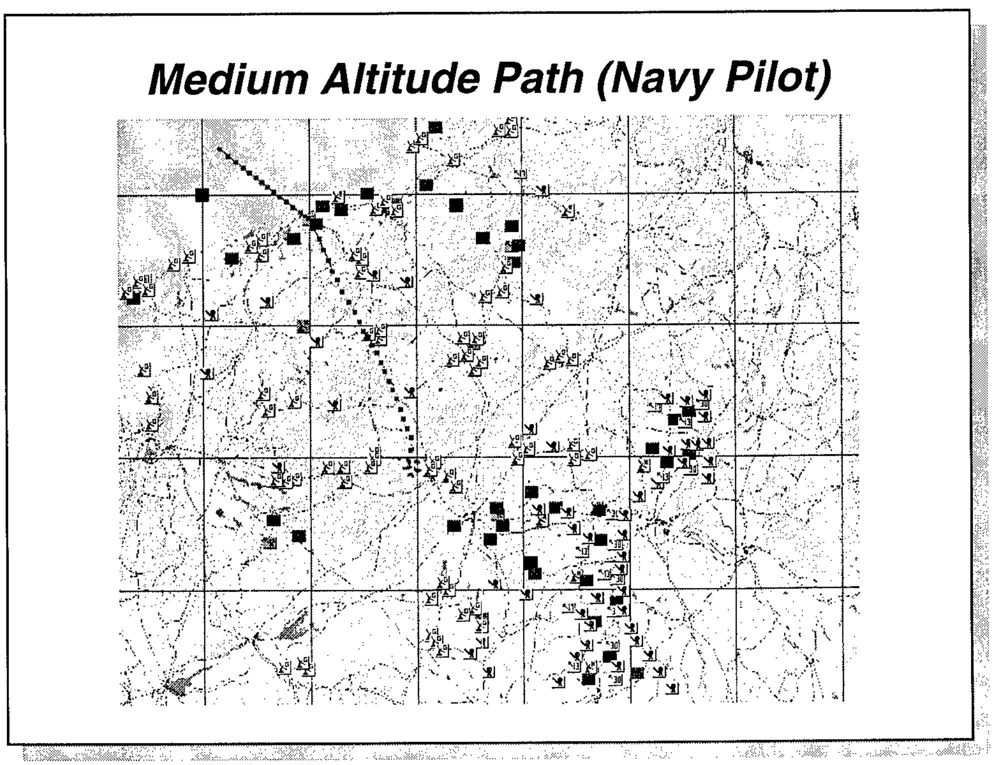
AD system	No SEAD	No SA-12, 17	No SA-12, 17 and Stealth
SA-12	0	0	0
SA-17	16	0	0
SA-15	0	0	0
SA-18	15	14	7
2S6	0	0	0
AAA	11	14	1
Total A/C lost	42*	28	8

*42 tilt-rotors flying cross-FLOT

The cross-FLOT mission was successful in avoiding SA-12s, SA-15s, and 2S6s due to good situational awareness of the location of these systems. The large number of SA-18s and AAA, however, limited mission survivability. Stealth (reduced optical and IR signatures) significantly reduced the number of aircraft atrited by these systems. A 20 percent attrition rate, however, is unacceptable for most vertical envelopment missions. IR jammers that are effective against SA-18 could reduce the attrition further, potentially to acceptable levels. Small arms fire as well as tanks and BMPs, however, were not included in this model and could significantly raise the number of losses.

Tactics and technologies for dealing with the optical and IR air defense threats need to be developed for the vertical envelopment air-mech concept to be viable.


Very Low & Slow Paths (Army Pilots)


Medium Altitude Path (Navy Pilot)

The missions shown up to this point were flown by non-Army aviators. TRADOC was asked and subsequently provided Army aviators to determine whether mission survivability could be increased by the appropriate use of TTPs.

Paths, as shown in the top figure on page 49, started out with 42 aircraft punching through one point along the coast and 42 aircraft punching through one point of the FLOT. After the initial ADA penetration each group of 42 split into three groups of 14. Paths were similar to previously presented cases (exceptions to this were the 20-foot AGL and 100-knot speed versus the previous case's 240-knot, 70-foot AGL). Paths from the ocean punch through at the SA-17 site, which was destroyed before the AAFs flew into the area. Cross-FLOT paths went through the city/town slightly in front of the FLOT, and between SA-15s on either side of the town.

Army Aviators' Vertical Envelopment Assumptions and TTPs

- **Extensive reconnaissance prior to mission.**
- **All emitters' positions known.**
- **Some fraction of nonemitter ADA assets known.**
- **Some fraction of enemy ADA can move during insertion mission.**
- **SEAD of certain critical SAM sites and airborne radar platforms.**
- **Mission flown with some vertical envelopment tilt-rotor attack aircraft.**
- **Real-time intelligence given to attack aircraft.**
- **Active radars and C2 sites will be suppressed during mission.**
- **Aircraft would fly at night/dusk to limit effectiveness of optically guided ADA.**
- **All aircraft make maximum use of SIRFC/SIRCM.**
- **Fixed-wing activity will diffuse the focus of threat ADA.**
- **Air Force and Navy will be flying tactical and/or operational missions during vertical envelopment insertion.**
- **Flight paths will be 20 feet above ground and 100 knots over suspected RF SAM covered/engagement areas.**
- **Vertical envelopment tilt-rotors will fly in groups of 14 in a tactical trail formation with a 50-meter separation.**

The aviators from U.S. Army Aviation School and Centers developed TTPs based on very specific assumptions. They included significant SA, SEAD, and other countermeasures, including diversionary activity designed to confuse and saturate the enemy's IAD network.

Aviation Schools' TTPs Did Not Significantly Change Mission Survivability Levels

	Mission			
AD system	**Ocean**	**Cross-FLOT**	**Ocean & Stealth**	**Cross-FLOT & Stealth**
SA-12	0	0	0	0
SA-17	0	0	0	0
SA-15	0	0	0	0
SA-18	10	11	5	4
2S6	0	0	0	0
AAA	2	9	0	2
Total A/C lost	12	20	5	6

***42 tilt-rotors per mission; flight path at 100 knots, 20-foot AGL over land**

The results of the excursions employing the U.S. Army Aviation School's TTPs were found to be comparable to cases already flown and examined (specifically those cases with high SA, high SEAD, and stealth). Again the limiting factors were the optical and IR air defense threats. Even at dusk these systems are effective, particularly since the aircraft flew within a few hundred meters of several AAA and SA-18 sites.

One method of countering the effects of low-altitude air defense systems is to fly above their engagement envelopes. These paths were flown by a Navy pilot and were above the range of AAA, MANPADS, 2S6s, and SA-15s. (See the bottom image on page 49.)

Flying Above the Range of 2S6s, AAA, and SA-15s Is Another Option

Need to suppress all long-range SAMs

- **SA-12s, 17s extremely effective against vertical envelopment aircraft (all killed in RJARS modeling)**
- **SA-15's maximum altitude is significantly increased for subsonic aircraft**
- **All tilt-rotors survive when SA-12s and 17s are suppressed**

Landing can be a potential problem

- **Size of vertical envelopment aircraft landing region/volume may be large**
- **No aircraft killed while landing in RJARS modeling (5.5-km diameter spiral landing path)**

The strategy of flying above the range of low-/medium-range SAMs was used successfully during Operation Desert Storm. As long as all long-range SAMs are suppressed, this strategy works.

Our analysis, however, shows two potential problems with this approach. First, if even one long-range SAM is active, large numbers of aircraft losses will occur. Drones, towed decoys, and aggressive SEAD can potentially deal with the long-range SAMs. This is a topic for future research. However, even if we suppress the long-range SAMs, our aircraft need to land in enemy territory. This implies that for a certain portion of the mission, the aircraft could be in the range of the short-range SAMs. If these two problems can be dealt with, then this is clearly a viable approach for vertical envelopment.

Air Maneuver Phase Insights

Lifters may be able to survive the mission if a combination of tactics and technologies are used:

- **Flying low and fast reduces exposure to high-altitude systems and minimizes time window for IR SAMs and AAA**
- **Situational awareness can help pilots avoid most, but not all, RF SAMs**
- **Stealth can reduce ranges of acquisition by optical and IR systems**
- **Significant amounts of SEAD of RF SAMs**
- **Flying high during most of insertion with suppression of high-altitude systems**

AAA, IR SAMs, and small arms will negatively impact mission survivability at low altitude

Analysis of the data from the ingress excursions yields the following insights:

1. Low-altitude ingress with some situational awareness of emitter locations can result in effective avoidance of SA-12s, and some SA-15s, SA-17s, and 2S6s. In our postulated enemy ADA scenario, not all RF SAM systems could be avoided.

2. High levels of SEAD will be needed to countermeasure emitting air defense systems. Even one long-range RF SAM site can inflict significant damage to the AAF squadron.

3. Optical and IR stealth is required to counter the effectiveness of AAA and MANPADS during low-altitude ingress.

4. Flying through areas of higher-density AAA and MANPADS (such as that encountered in the cross-FLOT) will lead to relatively high (~20%) aircraft losses.

5. Mid-altitude ingress is a viable option if the long-range SAMs can be suppressed and the landing area secured from AAA and MANPADS.

We now describe research issues for the ground combat phase. Preliminary results from a limited amount of ground vehicle research effort are also presented.

Focus of Ground Combat Phase

Explore different configurations of ground combat vehicles for survivability and lethality in vertical envelopment scenario

Critical vertical envelopment research question:

What are the characteristics of a deployable force capable of completing the range of vertical envelopment missions?

The primary goal of this research effort is to analyze different potential vertical envelopment battle forces as to their capabilities to conduct vertical envelopment missions, from early-entry to forced-entry missions. Critical to this analysis is the ability to determine the most deployable (i.e., most mobile, lethal, survivable, and sustainable) force capable of performing these missions.

Ground Combat Analysis Plan

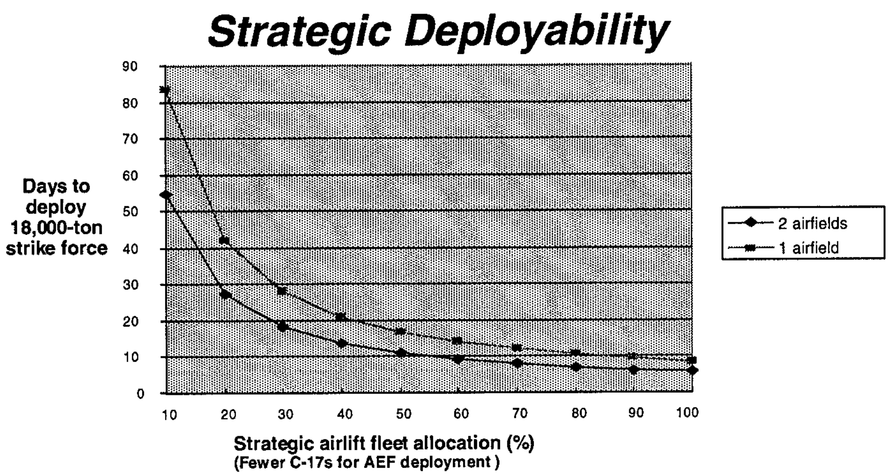
- Accurately model TRADOC vertical envelopment battle force
- Interact with ground vehicle development community to establish characteristics of ground vehicles
- Create challenging threat ground force (laydown, capabilities, and tactics)
- Use JANUS (with APS, MADAM, C2 models), CAGIS, and ASP to explore ground vehicle options
- Assess force performance using variety of MOEs

Our plan is to utilize the TRADOC-designed vertical envelopment battle forces as the basis for our Blue force analysis effort. Interactions with the combat vehicle design community and independent analysis at RAND will enable us to accurately model these forces. Concurrent with this effort, we will generate a challenging set of scenarios that will enable us to explore the capabilities of these strike forces via our high-resolution simulation tools. Lastly, we will assess force performance in the nonlinear vertical envelopment battlefield by using a variety of measures of effectiveness that can capture the impact of proposed vertical envelopment concepts, such as disruption, shock, and delay of enemy forces.

Vertical Envelopment Force Structure Will Need to Balance Conflicting Mission Needs

	Weight	Size	Support
Deployability	Minimize	Minimize	Minimize
Survivability	Maximize	Minimize	Neutral
Lethality	Maximize	Maximize	Maximize
Mobility	Minimize	Maximize	Minimize

Any vertical envelopment ground force will have to balance the need to be able to deploy from CONUS with the desire to have highly survivable and lethal combat vehicles. This, we believe, is the critical design issue for vertical envelopment ground forces. In the next several slides we present our initial exploration of these factors.

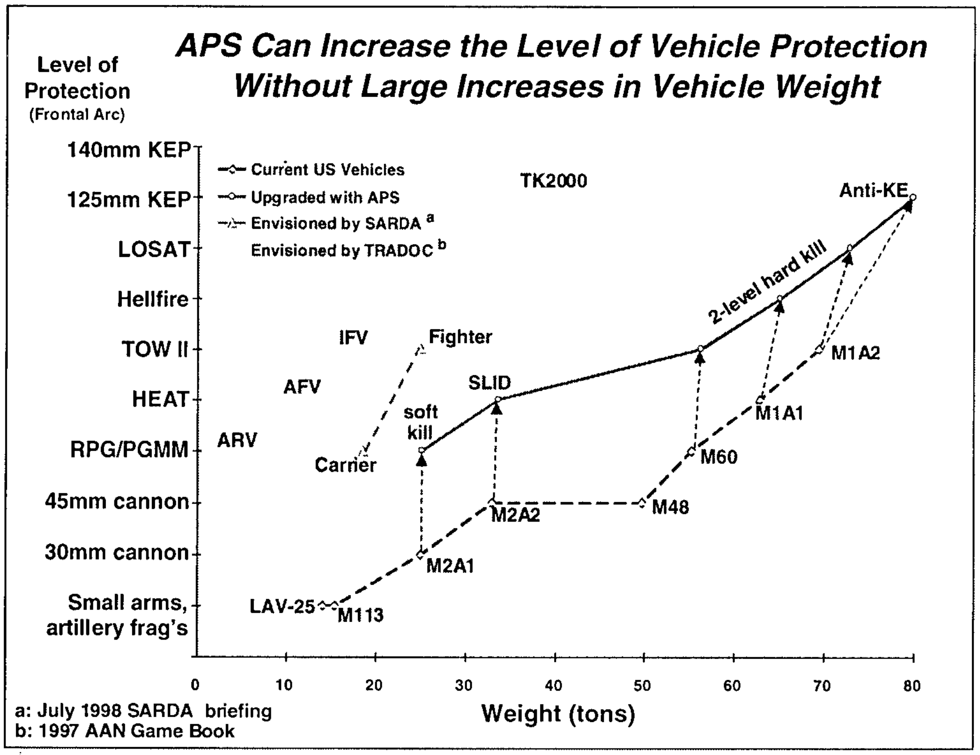


Air Force heavy lift fleet (2020)	**Operational rates for aircraft**
120 C-17s	**C-17: 82%**
126 C-5s	**C-5: 72%**
Cycle time for SWA deployment: 72 hours	**Sortie rate per airfield: 1 per hour**
C17s needed to deploy Air Expeditionary Force: 70	

To quantify the deployability issue we analyzed Air Force mobility command documents for proposed strategic lift capacity in the year 2020. The chart shows how fast an 18,000-ton strike force would be deployed, assuming different levels of available lift and numbers of airfields. For example, with two airfields and 100 percent of strategic lift, one task force would deploy in six days by air. Shorter deployment distances, more airfields, and faster ground operations could reduce this time to under five days. To first order, however, our initial analysis indicates that strategic lift will limit how fast the vertical envelopment force can be deployed.

Combinations of lighter forces and prepositioned equipment should be analyzed to enhance the deployability of the force. Other deployment options, such as fast ships, could also be examined.

Further research on deployment options will be critical as the vertical envelopment battle force is further defined.

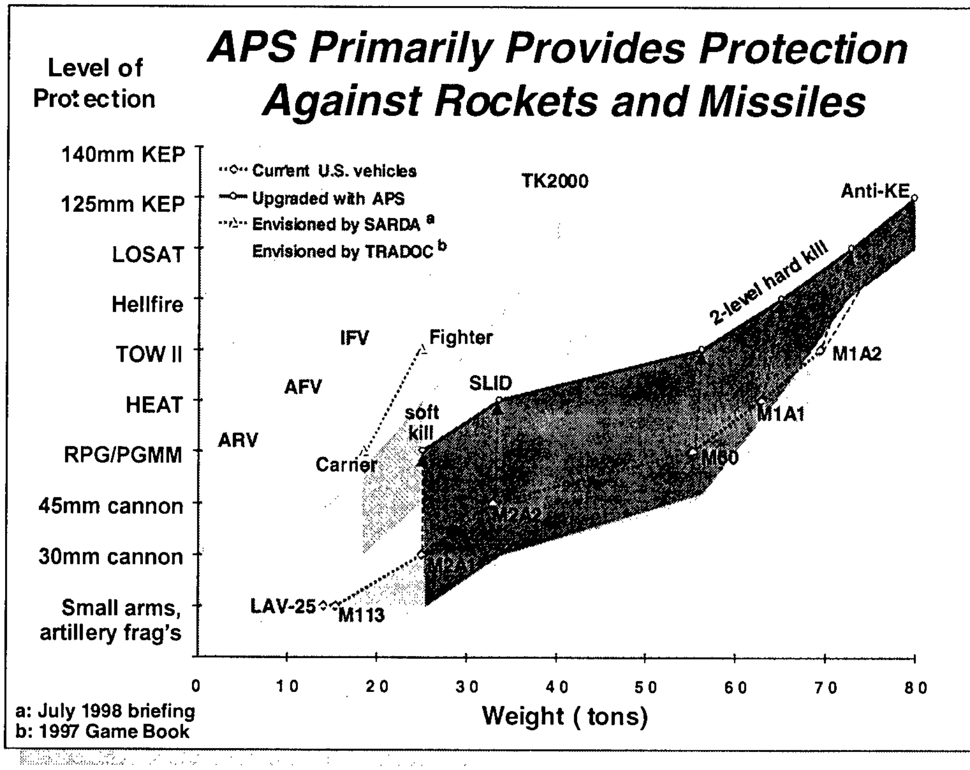


This chart illustrates two important vertical envelopment issues. First, it shows where SARDA and TRADOC have envisioned future vehicles will be in terms of protection and weight. Second, it shows the degree of extra protection that active protection systems (APS) can provide to existing vehicles with relatively small increases in vehicle weight. The APS consists of a sensor that detects an incoming missile and a neutralizing mechanism, such as an intercept missile or an exploding cloud of ball bearings.

The y-axis on this chart indicates the maximum level of protection associated with a vehicle, in terms of the most lethal type of threat that it can protect itself from under ideal circumstances. Such protection generally occurs when a threat is approaching the front of the vehicle, where the armor is thickest, and the APS (if any) performs as intended.

A selection of U.S. vehicles currently in use are shown along the bottom, dotted line. The line above it shows the level of protection that a subset of these U.S. vehicles would have if upgraded with various types of APS. The dashed arrows connect current vehicles to their corresponding APS variants, and the labels indicate the particular APS type.

The vertical envelopment battle force, shown as a short dotted line, includes two different types of vehicles: an 18.5-ton carrier vehicle and a 25-ton fighting vehicle. The TRADOC vehicles, shown in the light-shaded line, include two "Blue force" vehicles—the 7.5-ton Advanced Reconnaissance Vehicle (ARV) and the 15-ton Advanced Fighting Vehicle (AFV)—as well as two "Red force" vehicles—the 20-ton IFV and the 40-ton TK2000. Current TRADOC concept vehicles are heavier. These sets of future vehicles represent a significant increase in protection capabilities for a given vehicle weight. The feasibility of these and other future vehicles is a major DARPA-Army research activity.



This version of the protection-versus-weight chart shows an estimate of the minimum level of protection for each set of vehicles, as indicated by the lower boundary of the shaded area under each curve. This minimum level is represented by the most lethal type of threat that the vehicle can protect itself from, with high reliability, under challenging circumstances. In particular, these include situations in which a threat is approaching the vehicle from above or from the rear, where its armor is thinnest.

The most notable feature of this chart is the narrowing of the protection "wedge" for APS-upgraded vehicles, shown by the darkest shading. This indicates that adding a low-end APS to lightweight vehicles does not raise their ballistic protection level, while adding a high-end APS to heavier vehicles does raise their protection level. The reason for this difference is quite intuitive. Lighter vehicles must rely on their relatively thin armor to protect themselves against intermediate threats. For example, a vehicle with 30mm cannon minimum protection can add an APS to boost its maximum protection from rocket propelled grenades (RPG), but this would not raise its ballistic protection level, since the APS cannot address 45mm cannon threats. Heavier vehicles, however, can handle these intermediate KE threats because they have

better passive protection. This additional armor also aids the APS in the protection against large KE threats. This happens because high-end APS work by breaking up the large KE projectiles. The armor on these vehicles will be needed to stop the projectile fragments from penetrating.

Increased Vehicle Weight May Significantly Improve Survivability

Armor	8–10 ton	20 ton	30 ton
Passive	7.62 mm (All Around) HE Fragments	14.5 mm (All Around) HE Fragments	30 mm (All Around) HE Fragments
Reactive		Unitary Warhead CE Missiles & RPGs	Unitary Warhead CE Missiles & RPGs
APS		ATGMS	ATGMS & KEP (<105mm)

Research of the open literature and discussions with TARDEC led us to postulate the above weight-versus-protection table. Our estimates indicate that 30-ton vehicles may be needed for vertical envelopment missions where the force is exposed to direct-fire weapons. We also note the difficulty of designing lightweight vehicles capable of surviving a direct-fire fight with an enemy main battle tank.

The need for heavy armor will be a function of the proposed vertical envelopment mission. Lighter vehicles can be considered if direct-fire fights are avoided and heavy indirect-fire missiles are not expected. We note that TRADOC has avoidance of the direct-fire fight as a key element of the AAN battle force TTPs.

Future Research: Analysis of Technologies Critical to Vertical Envelopment

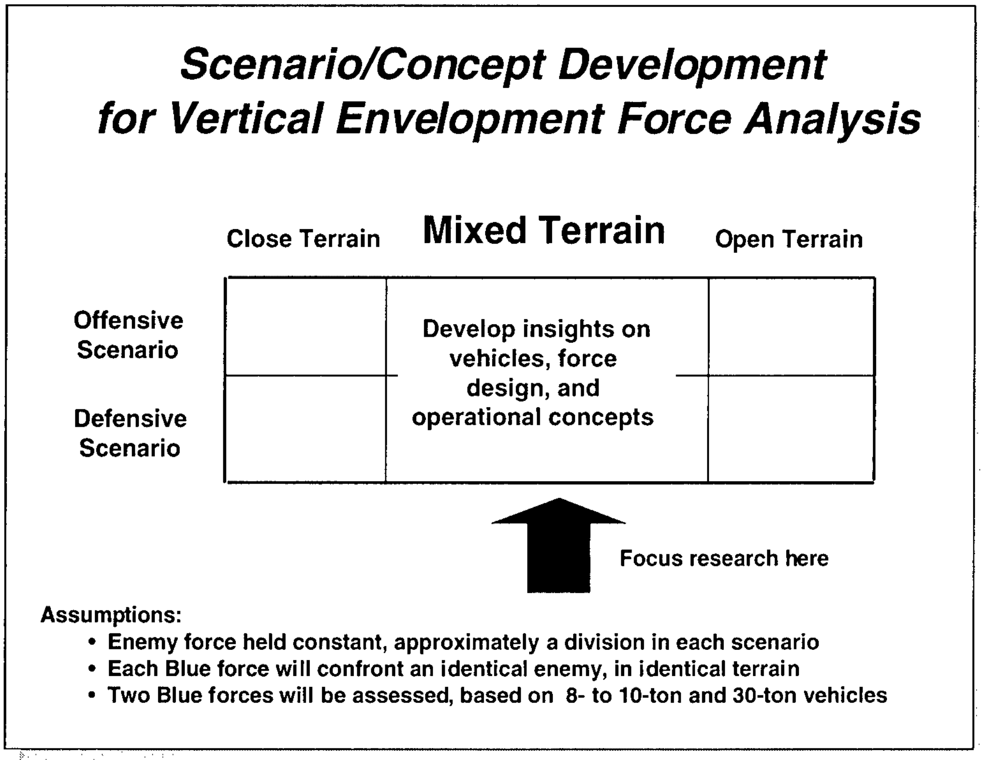
What technologies are needed for vertical envelopment concepts?

- **Lightweight armor**
- **Active protection systems**
- **Robotics**
- **Propulsion systems**
- **Sensors**
- **Indirect-fire weapons**
- **Others**

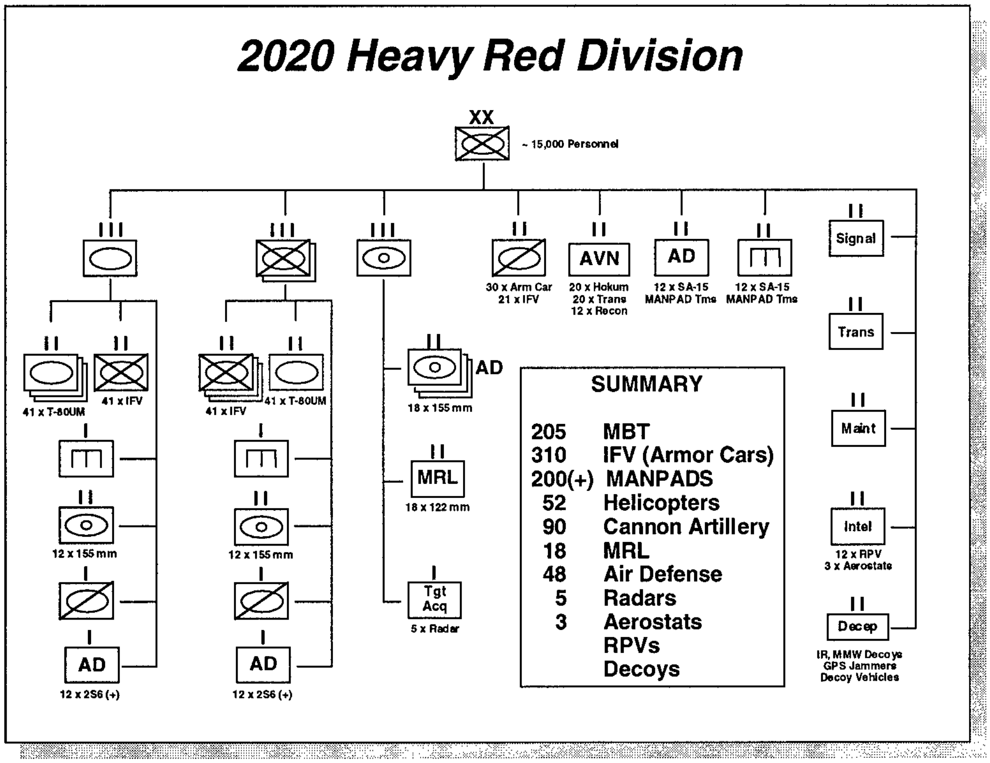
Approach: Assess technologies that can provide mission essential force attributes. Use high-resolution modeling to refine/assess needed attributes.

Vertical envelopment mission issues such as survivability, lethality, and mobility will require innovative application of many different technologies. Unlike lightweight armor, which can be readily quantified as to its impact on vehicle survivability, other technologies will have a more complex set of effects on desired battle force capabilities. Robotics, for example, can reduce the number of human casualties (by reducing the number of manned vehicles on the battlefield), provide greater amounts of firepower per soldier, and enable greater mobility (active suspension). New propulsion systems can increase not only mobility, but also survivability. Sensors that can penetrate foliage could increase both lethality and survivability.

High-resolution modeling can be performed to help quantify these capabilities.

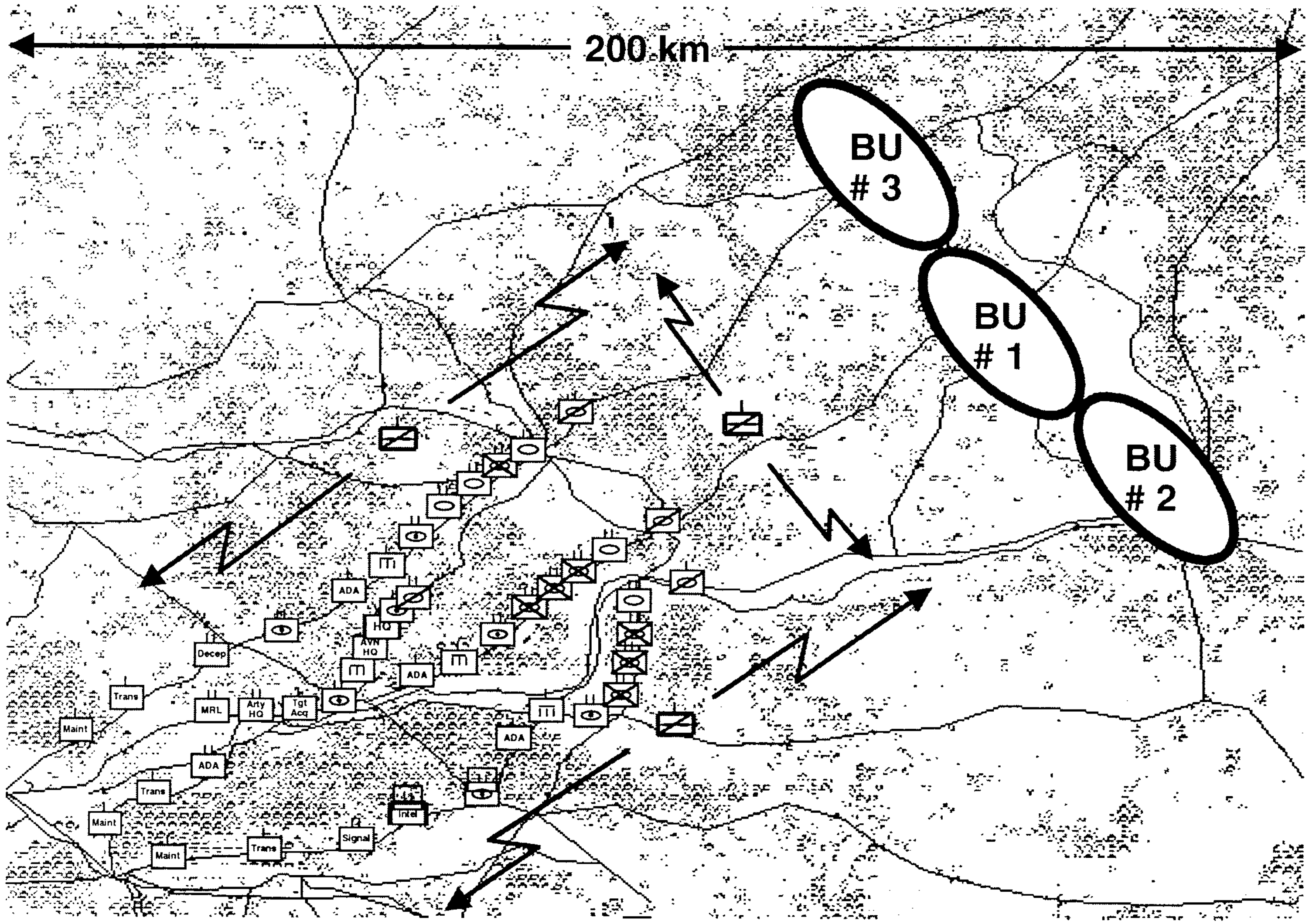


Program limitations usually require a judicious selection of the small number of scenarios/vignettes we can analyze. We plan to use a single scenario with a variety of mixed terrain to enable us to see effects resulting from both open and close terrain. We also plan to develop one offensive and one defensive vignette. Vertical envelopment forces with different vehicle weight classes will then be examined. While the total number of cases examined will be limited, we believe the range of parameter space explored will be sufficient to provide key insights on vertical envelopment concepts.



The composition of the enemy division is shown in this chart. We base the force structure on current Russian doctrine. Equipment selection is based on our estimate as to what will be available in the international market in the 2020 time frame. Again, we are selecting a threat that will not be state of the art, but one that a second-world country can afford and man. This division should be considered a starting point for analysis; more capable divisions should be considered in later phases of the research.

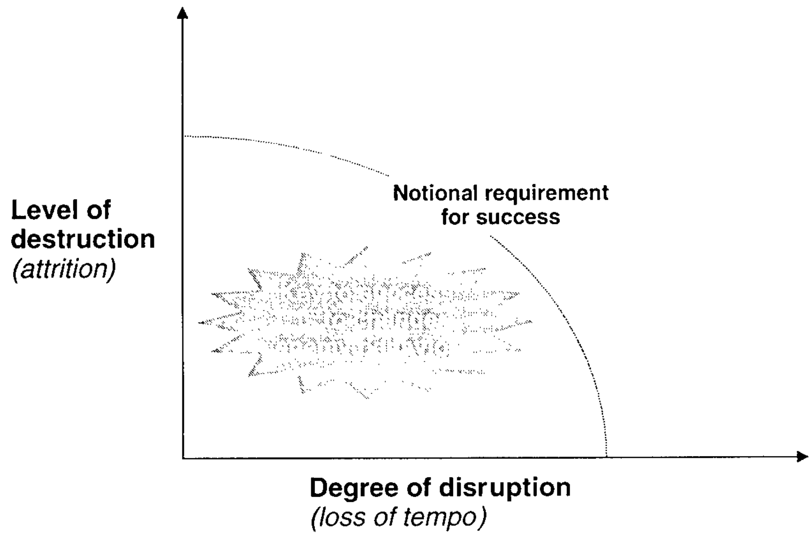
Laydown of Enemy Ground Force
Modified 2020 Division—Blue Force Defense



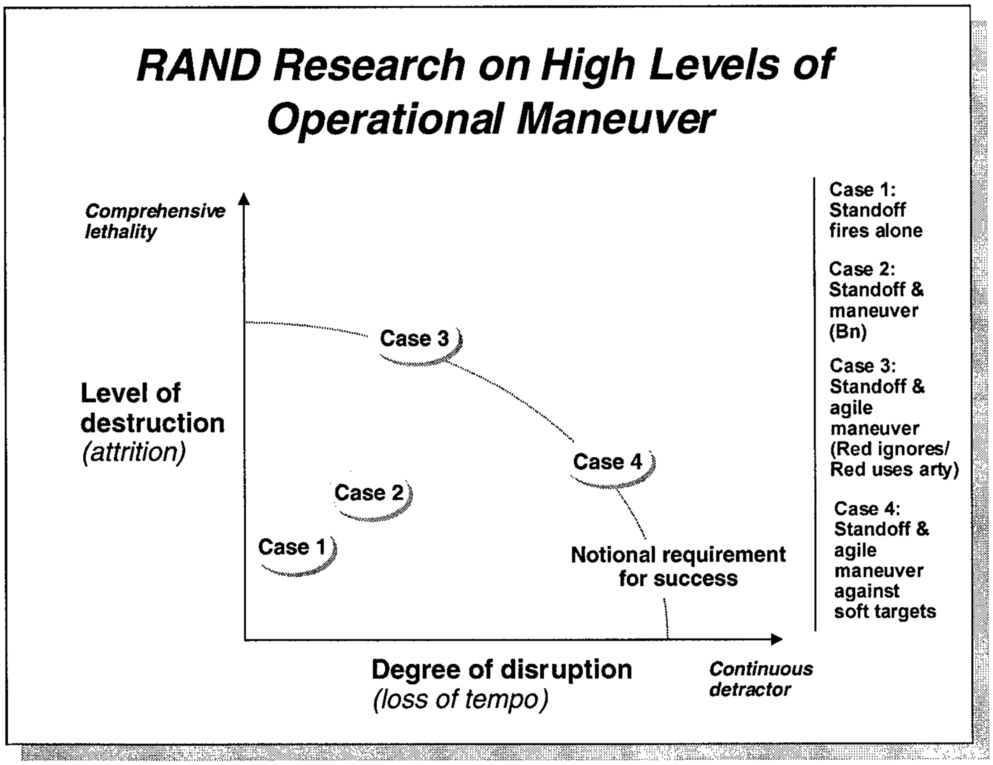
Our initial estimate of the laydown of the enemy division ground force is shown in the figure on page 68. In our defensive scenario, the enemy division attacks three vertical envelopment battle units.

The area shown on the map is roughly the size of the Kuwaiti theater of operations (KTO) during the 1991 Persian Gulf War, approximately 250×250 kilometers. The terrain is that of Poland. It consists of open spaces mixed with mountains, cities, and forests.

Effectiveness Can Be Gauged by Level of Destruction <u>or</u> Degree of Disruption



Assessments of the different vertical envelopment concepts begin with enemy attrition (and own losses) as the primary measure of effectiveness (MOE). The dynamics of the nonlinear vertical envelopment engagements are such that disruption of the enemy operation—denying him the ability to move or resupply, slowing his progress, dispersing his forces, or degrading his coordination capabilities—may be as important as attrition. Shock effects (heavy losses over a short time, in small areas, or of key systems) may also disrupt the advance.



RAND has performed research on rapidly deployable vertical envelopment–type forces for over a decade. This chart shows the results of recent work for the Defense Science Board (DSB).* We believe this "spanning the range" analysis has implications for vertical envelopment analysis. The salient points of this RAND analysis on high levels of operational maneuver are presented below.

Case 1, which involved the aggressive use of standoff fires, resulted in a less-than-decisive 12 percent attrition of the overall enemy force. One advantage of this concept was that because direct exposure to the enemy was minimal, no losses occurred—assuming high-altitude JSEAD was successful. Case 2, which involved both standoff fires and what might be considered a conventional ground force insertion, provided somewhat increased lethality (and robustness), but at the cost of considerable losses to the U.S. force.

Case 3, involving the insertion of medium-weight strike force teams to ambush the enemy, represented a substantial increase in lethality

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*John Matsumura et al., *Joint Operations Superiority in the 21st Century: Analytic Support to the 1998 Defense Science Board,* Santa Monica, CA: RAND, DB-260-A/OSD, 1999.

from cases 1 and 2. Organic direct and indirect fires each contributed as many kills as standoff fires. In fact, due to the shock of the ambush, enemy losses of 50 percent demonstrated in case 3 may well be sufficient to disrupt the enemy march. If so, fewer direct-fire ambushes may need to be triggered, reducing U.S. losses further.

In case 4 the same strike force teams engage resupply and C2 elements rather than combat elements. This represents a significant departure from the way we think about assessing force effectiveness. Rather than a force-on-force engagement analysis, this tends to be a force effects analysis, where most of the effects may be non-attrition-based. Thus, to some extent we've only begun to characterize the effects of this concept. Initial work indicates this case results in substantial amounts of disruption.

RAND DSB Study Insights Relevant to Vertical Envelopment Concept Development and Analysis

Combination of engagement and maneuver capabilities is required for joint force robustness

- **Standoff engagement offers tremendous potential to shape battle conditions, but comes with key physical limitations**
- **Agile maneuver allows control of terrain and enemy action, but comes with inherent risk**

New strategic and operational mobility capabilities, to some extent, may be able to offset each other

Lighter ground force systems may be required for agile maneuver (early-entry) missions

Weapons may be limiting factor for standoff engagement

Responsiveness of fires is critical when the enemy can move between cover

Foliage penetration can be critical for both sensors and weapons

Insights from our Defense Science Board research also highlight critical research issues for the vertical envelopment ground force.

The DSB work showed that standoff munitions by themselves may not be able to stop an advancing enemy. Specifically, they can be poorly matched to an enemy using speed and cover during his advance. They can, however, shape the battlefield and significantly enhance the effectiveness of the ground maneuver force. Future vertical envelopment analysis needs to include and optimize the role of standoff munitions.

The limited ability to transport forces from CONUS can be balanced out, to a certain extent, by quickly transporting the forces about the battlefield. Overall vertical envelopment mission success will depend heavily on understanding the balance needed between strategic and operational mobility capabilities.

Lastly, the DSB analysis showed that a thinking enemy can be very difficult to defeat. His ability to use cover when moving, utilize netted air defense, disperse his forces, and mix the types of vehicles in the force makes conventional attack options decreasingly effective.

Outline

- Methodology
- Scenario
- Air maneuver phase
- Ground combat phase
- **Insights**

The last section summarizes the insights from work we performed in 1998. The study, which was originally intended to be a multi-year research effort, was limited in what research could be and was performed in one year. We present these insights with the caution that they represent our initial assessments of a highly complex problem. The insights are meant to be helpful suggestions for focusing some research efforts on areas we believe will be important for the success of General Shinseki's vision of the medium-weight Objective Force.

Insights

Lifters may be able to survive mission if combination of tactics and technologies are used:

- **Flying low and fast stealthy aircraft with good situational awareness, and SEAD of critical SAM sites**
- **Flying high during most of the insertion with suppression of high-altitude systems**

Methods to suppress/neutralize AAA, IR SAMs, and other man-portable weapons need further research and development

Medium-weight vehicles may be able to engage the enemy in a direct-fire fight up to the 105mm cannon level

Strategic lift capability will limit the type of vertical envelopment force that can be deployed from CONUS

The study, while limited in its efforts, did generate some initial insights that we believe are important observations for research activities currently being performed for General Shinseki's transformation vision and resultant Objective Force.

This study concentrated on the air-insertion phase of the vertical envelopment air-mech concept. We demonstrated that there were two approaches that could enable the ground force to be inserted. Flying low enables the usage of terrain masking and is appropriate in areas where long-range SAMs are operating. Flying high works better if long-range SAMs are suppressed.

Knowledge of the SAM site locations was shown to enhance aircraft survival rates. In several cases, however, the pilot could not always avoid these sites. While in most cases these missions would not be flown, there may be cases where there is no choice. Developing TTPs and new countermeasure technology is essential for the successful execution of these current high-risk missions.

Finally, we note that optically and IR guided ADA systems will be hard to detect and can limit vertical envelopment aircraft survival rates.

Our ground vehicle research showed that lightweight armor and APS technologies could be used to build medium-weight vehicles (20–30 tons) capable of surviving attacks from weapon systems up to a 105mm cannon round.

Lastly, we examined the Air Force's strategic lift capability, and our initial analysis indicated that it is limited to about 3,000 tons a day. The vertical envelopment force design needs to reflect this limited air deployment capability.

Air Maneuver Phase: Unanswered Questions

Technology

- **The effects of small arms fire on mission survivability**
- **Future RF, IR, and AAA countermeasures**
- **New optical and IR stealth concepts**

Investigation of alternative air-insertion tactics

- **Fly to perimeter of enemy air defenses; then drive vehicles to fighting locations**
- **Unmanned insertion of vehicles**
- **SOF-aided missions**
- **Cross-FLOT ADA suppression techniques**

The air-insertion analysis performed in this study provided significant insights. Due to its limited duration and scope, the study identified but did not fully examine two critical areas of research.

One key area for further research is to develop an understanding of the limiting effects of optically guided anti-aircraft munitions. Further study is needed to better quantify the magnitude of this problem. Given its potential severity, additional research on technologies to counter this problem is also warranted. One approach in particular, stealth fixed-wing aircraft, could potentially provide a viable, but expensive, solution to this problem. Another solution is to develop new air-insertion tactics, the second critical area of future research efforts.

In this initial study we looked at only two sets of air-insertion tactics. Other tactics listed on this chart have the potential to significantly raise the probability of successful insertion of the vertical envelopment battle force.

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Analysis of Air-Based Mechanization and Vertical Envelopment Concepts and Technologies

In the Army After Next (AAN) concept of rapidly deployable mechanized battle forces in a tactical environment, the forces will be transported by vertical, or near-vertical, lift aircraft. In the nonlinear AAN battlefield, this may require the forces to be deployed near the enemy's second echelon. The authors examined the performance of the notional AAN advanced airframes to survive this initial air maneuver/insertion under a variety of conditions.

Using high-resolution constructive simulations, the authors assess the airframes' survivability against an integrated air defense system operating in mixed terrain. The results indicate that no one approach can guarantee aircraft survivability. Combinations of aggressive SEAD, use of stealth technology, and enhanced situational awareness can, under certain conditions, result in good survivability rates for the aircraft. But the large size and slow flight speeds of the aircraft make them susceptible to optically guided munitions. New technologies, tactics, and techniques will be needed to deal with this threat if the AAN air insertion concept is to succeed.

ISBN 0-8330-2966-5

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DB-321-A